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MUNICIPAL WASTE COMBUSTORS - BACKGROUND INFORMATION FOR PROPOSED STANDARDS: 111(b) MODEL PLANT DESCRIPTION AND COST REPORT

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Municipal Waste Combustors- Background Information for Proposed Standards: 111(b) Model Plant Description and Cost Report

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Twelve model plants are developed to represent the projected municipal waste combustor (MWC) industry. The model plants selected represent new MWC's expected to be constructed in the United States between 1990 and 1994. The model plants differ with respect to unit size and design, waste feed characteristics, heat recovery method, and flue gas emissions. The model plants provide a basis for estimating emission reductions, costs, and other impacts for various control alternatives.

Information is provided on capital and operating and maintenance (O&M) costs of the model plants and control equipment. For each model plant, an assessment of baseline and three emission control options based on costs, emission reduction, cost effectiveness, and energy and environmental impacts is provided. Baseline capital and O&M costs for each combustor type include costs of good combustion and PM control with electrostatic precipitators (ESP's). The costs of three emission control options are also presented. All costs are presented in December 1987 dollars.

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FINAL REPORT

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1.0 INTRODUCTION

This report describes the operating and emission parameters, and costs for new municipal waste combustor (MWC) model plants developed to support the impacts analysis of new source performance standards (NSPS) for this source category. Twelve different model plants were selected to represent the MWC industry based on differences in unit size and design, waste feed characteristics, heat recovery method, and flue gas emissions. The model plants were selected to represent new MWC's expected to be constructed in the United States between 1990 and 1994. These plants were developed to provide a basis for estimating emission reductions, costs, and other impacts of the various control alternatives under consideration.

The model plants include three mass burn/waterwall (MB/WW), one mass burn/refractory (MB/REF), one mass burn/rotary combustor (MB/RC), one modular/excess air (MI/EA), two modular/starved air (MI/SA), two refuse-derived fuel (RDF), and two fluidized-bed combustion (FBC) facilities. These model plants are summarized in Table 1-1. It is assumed that all of the model plants except the 50 ton per day (TPD) MI/SA plant will generate electricity. Most plants will fire 100 percent municipal waste or RDF, but one of the RDF model plants will cofire a 50/50 mixture of RDF and wood. Primary design parameters specified for each model plant are listed in Table 1-2 and include: combustor type, plant size, number of combustors per plant, excess air level, waste feed ash content, flue gas flowrate and temperature, and particulate matter (PM), sulfur dioxide (SO_2), hydrochloric acid (HCl), carbon monoxide (CO) and total dioxin/furan (CDD/CDF) concentrations and annual emission rates exiting the combustor. All flue gas concentrations are reported on a 7 percent O_2, dry basis.

Acid gas (HCl and SO_2) emissions and flue gas flowrates were calculated based on the feed waste composition specified in Table 1-3 and the excess air rates given in Table 1-2 using a software package developed by Pacific Environmental Services (PES).[1] The acid gas emission estimates assume that the entire sulfur and chlorine components of the incoming feed are converted to SO_2 and HCl, respectively, upon combustion. Excess air levels, flue gas temperatures, and PM, CO, and total CDD/CDF emissions were developed and documented in a separate report.[2]

TABLE 1-1. MODEL PLANT SELECTION FOR 111(b)

Model plant number	Combustor type	Unit size, (TPD)	Number of combustors	Total plant capacity, (TPD)	Annual operating hours	Heat recovery	Fuel
1	Mass burn/waterwall	100	2	200	5,000	Steam	100% MSW
2	Mass burn/waterwall	400	2	800	8,000	Electricity	100% MSW
3	Mass burn/waterwall	750	3	2,250	8,000	Electricity	100% MSW
4	Mass burn/refractory	250	2	500	8,000	Electricity	100% MSW
5	Mass burn/rotary combustor (waterwall)	350	3	1,050	8,000	Electricity	100% MSW
6	Refuse-derived fuel	500[b]	4	2,000	8,000	Electricity	100% RDF
7	Refuse-derived fuel	500[b]	4	2,000	8,000	Electricity	50% RDF/ 50% wood
8	Modular excess air	120	2	240	8,000	Electricity	100% MSW
9	Modular/starved air	25	2	50	5,000	None	100% MSW
10	Modular/starved air	50	2	100	8,000	Electricity	100% MSW
11	Fluidized-bed combustion (BB)[c]	450[b]	2	900	8,000	Electricity	100% RDF
12	Fluidized-bed combustion (CFB)[d]	450[b]	2	900	8,000	Electricity	100% RDF

[a] 24 hrs/day x 333 days/yr = 8,000 hrs/yr
100 hrs/wk x 50 wk/yr = 5,000 hr/yr

[b] Unit size represents TPD RDF for Model Numbers 6, 11 and 12 and represents combined RDF and wood for Model Number 7.

[c] BB = Bubbling bed

[d] CFB = Circulating fluidized-bed

TABLE 1-2. MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model Plants[a]											
	Small MB/WW (No. 1)	Medium MB/WW (No. 2)	Large MB/WW (No. 3)	MB/REF (No. 4)	MB/RC (No. 5)	RDF (No. 6)	RDF (Cofired) (No. 7)	MI/EA (No. 8)	MI/SA (No Heat Rec.) (No. 9)	MI/SA (No. 10)	FBC/BB (No. 11)	FBC/CFB (No. 12)
Facility Specification												
No. of combustors per model	2	2	3	2	3	4	4	2	2	2	2	2
Total daily charge rate, TPD	200	800	2,250	500	1,050	2,000	2,000	240	50	100	900	900
Annual operating hours	5,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	5,000	8,000	8,000	8,000
Ash content of feed waste, %[b]	22.2	22.2	22.2	22.2	22.2	7.5	4.3	22.2	22.2	22.2	7.5	7.5
Excess combustion air, % of theoretical	80	80	80	200	50	50	50	100	100	100	60	60
PM emission factor, % of feed waste ash[b]	10	10	10	10	10	80	80	0.50	0.50	0.50	80	80
Baseline PM emission rate, gr/dscf:	0.08	0.05	0.05	0.08	0.05	0.05	0.05	0.08	0.1	0.08	0.01	0.01
Stack height, ft	140	200	230	150	125	200	200	70	60	60	200	200
Stack diameter, ft	4.0	6.0	7.0	9.0	5.0	8.0	8.0	6.0	5.0	5.0	6.0	6.0
Number of stacks	2	2	3	2	3	4	4	1	1	1	2	2
Flue Gas Data Per Combustor[c]												
Volume flowrate:												
dscfm	11,500	46,000	86,200	48,100	33,400	58,700	52,000	15,300	3,200	6,400	56,400	56,400
scfm	13,300	53,100	99,500	52,500	39,600	68,500	62,600	17,500	3,600	7,300	65,200	65,200
acfm	22,800	91,100	171,000	90,200	68,100	118,000	107,000	30,000	14,100	12,500	99,700	99,700
Outlet temperature °F	450	450	450	450	450	450	450	450	1,600	450	350	350

Continued

TABLE 1-2 (CONCLUDED). MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model Plants[a]											
	Small MB/WW (No. 1)	Medium MB/WW (No. 2)	Large MB/WW (No. 3)	MB/REF (No. 4)	MB/RC (No. 5)	RDF (No. 6)	RDF (Cofired) (No. 7)	MI/EA (No. 8)	MI/SA (No Heat Rec.) (No. 9)	MI/SA (No. 10)	FBC/BB (No. 11)	FBC/CFB (No. 12)
Emission Concentrations per combustor at 7% O_2 (dry)[d]:												
Particulate Matter:												
mg/dscm	4,600	4,600	4,600	4,600	4,600	9,200	9,200	4,600	230	230	9,200	9,200
(gr/dscf)	(2)	(2)	(2)	(2)	(2)	(4)	(4)	(2)	(0.1)	(0.1)	(4)	(4)
CO, ppmv	50	50	50	100	100	100	100	100	50	50	50	100
CDD/CDF, ng/dscm	200	200	200	300	300	1000	1000	200	300	300	20	400
Acid gas:												
HCl, ppmv	500	500	500	500	500	500	250	500	500	500	350	350
SO_2, ppmv	200	200	200	200	200	300	150	200	200	200	240	240
Annual Emissions per combustor[d]												
PM, tons/yr	408	2,610	4,890	1,630	2,280	8,030	7,130	783	5	16	7,220	7,220
CO, tons/yr	5	33	62	41	58	102	90	22	2	4	22.8	46.2
CDD/CDF ($\times 10^{-2}$), lbs/yr	3.56	22.8	42.8	21.4	29.8	176	156	6.84	1.34	4.28	3.16	63.3
HCl, tons/yr	69	439	823	274	383	669	326	132	17	55	503	503
SO_2, tons/yr	50	320	601	200	280	666	368	96	13	40	417	417

[a] MB/WW - mass burn/waterwall, MB/REF - mass burn/refractory, MB/RC - mass burn/rotary combustor, MI/EA - modular/excess air, MI/SA - modular/starved air, RDF - refuse-derived fuel, and FBC - fluidized-bed combustion.

[b] From Report to Congress.

[c] Calculated based on the facility specifications in this table and the feed waste composition data from Table 1-3.

[d] Emissions at combustor exit. Annual emissions from the stack are included in Section 7.0. At baseline, excluding Model Plant No. 9, stack emissions of PM are assumed to comply with the 0.05 gr/dscf or 0.08 gr/dscf limits as required by 40 CFR 60, Subparts Db or E. (Model Plant 9 is smaller than the 50 TPD combustor size cutoff in Subpart E.) Baseline controls would not affect emissions of the other pollutants listed, and stack emissions would be the same as listed above.

TABLE 1-3. FEED WASTE COMPOSITION DATA[1]
(Weight Percent)

Constituent	MB and MOD plants	RDF and FBC plants	RDF Cofired plant[a]
Carbon	26.7	33.8	30.4
Hydrogen	3.6	4.5	3.7
Oxygen	19.7	27.9	23.5
Sulfur	0.1	0.2	0.1
Nitrogen	0.2	0.5	0.3
Water	27.1	25.2	37.6
Chlorine	0.3	0.4	0.2
Inerts	22.2	7.5	4.3

[a] 50/50 mixture (mass basis) RDF and wood; calculated using following equation:

$$\text{constituent (mixture)} = \left(\frac{\text{constitutent (RDF)} + \text{constituent (wood)}}{2}\right)$$

where,

wood composition (weight percent) is as follows: 26.9 percent carbon, 2.9 percent hydrogen, 19.1 percent oxygen, 0.02 percent sulfur, 0.08 percent nitrogen, 50 percent water, 0 percent chlorine and 1 percent inerts.

The emission estimates are representative of typical combustors in each subcategory of MWC's.

In addition, annual operating hours and heat recovery capabilities are presented in Table 1-1. These parameters were selected to be representative of new plants in each subcategory based on the available information. Representative stack heights and diameters presented in Table 1-2 were derived from information contained in a survey of all existing MWC's.[3] These parameters are discussed further in subsequent sections.

Information is provided in this report on capital and operating and maintenance (O&M) costs of the model plants and control equipment included in the baseline. For each model plant, an assessment of baseline and three emission control options based on costs, emission reduction, cost effectiveness, and energy and environmental impacts is provided. Baseline capital and O&M costs for each combustor type include costs of good combustion and PM control with electrostatic precipitators (ESP's), except for the smallest modular plant (no. 9), which is assumed not to have an ESP at baseline. The costs of three emission control options are also presented. All costs are presented in December 1987 dollars.

The remainder of this report is organized as follows: Section 2.0 presents background information and methodology for model plant selection, a description of baseline emissions control and the three other control options, and an overview of costing procedures; Sections 3.0 through 6.0 present a brief description of the model plant parameters and the projected number of new MWC facilities subject to the NSPS in the 5-year period after proposal for each model plant listed above; and Section 7.0 presents costs, emission reduction, and cost effectiveness of the emission controls for each model plant selected; Section 8.0 lists the references.

2.0 BACKGROUND

2.1 METHODOLOGY FOR MODEL PLANT SELECTION

Model plants were developed for the purpose of calculating emission reduction and control cost information for new MWC's expected to commence construction within 5 years after the proposal date of the NSPS, scheduled for November 1989. The number of combustors and total capacity of facilities expected to be subject to the NSPS nationally were estimated from market predictions of waste generation and disposal practices. Based on this approach, it was estimated that total annual waste combusted in the fifth year after proposal of the NSPS will be 16.5 million tons/yr, and total design capacity will be 19.6 million tons/yr.[4] This equates to a total design capacity of 54,000 TPD subject to the NSPS in the 5-year period after proposal. However, because these facilities will not commence construction for several years, in many instances, the combustor type, size, or number is not known. Therefore, in developing model plants, it was assumed that recent trends in combustor type, size, and number of combustors per plant will continue through 1994 (5 years after NSPS proposal). This is a reasonable assumption since, for the NSPS facilities for which information is available, the distribution of the number of facilities and total design capacity appears similar to those facilities commencing construction prior to 1989.

To estimate the distribution of new MWC's by combustor type, information on facilities in advanced planning or early construction stages was used. These distributions indicate that of the projected total design capacity of 54,000 TPD subject to the NSPS: 64 percent of capacity will be mass burn, 27 percent RDF, 3 percent modular, and 7 percent FBC or gasification facilities.[5]

To determine combustor and plant size, a list was prepared containing all recently built facilities (start-up dates of 1985 or later) and those facilities in the advanced planning or construction stages for which data on combustor type, size, and number of combustors are available. Existing combustors were added to provide a larger data base. These data were sorted by combustor type, and combustor and plant size distribution lists and graphs were prepared. Typical plant and combustor size for each combustor type as well as number of combustors per plant were then determined from reviewing these lists and the unit and plant size distribution graphs. The number of plants subject to the NSPS was then calculated by dividing the total national capacity for each plant type by the size of the model plant. The number of combustors was calculated by multiplying the number of plants by the number of combustors in the model plant. A summary of the numbers of plants and combustors is given in Table 2-1.

2.2 DESCRIPTION OF BASELINE AND THREE CONTROL OPTIONS

Four different control technologies were combined into three control alternatives. The various control technologies address CDD/CDF, PM, SO_2, and HCl emissions and include both combustion control methods which promote the destruction and inhibit the formation of some pollutants (e.g., CDD/CDF), and post-combustion exhaust gas control methods. The four control technologies are:

(1) good combustion practices including exhaust gas cooling;
(2) electrostatic precipitator (ESP);
(3) dry sorbent injection with fabric filter (FF) (or ESP); and
(4) spray dryer with FF.

Good combustion practices (GCP) include the proper design, construction, and operation of an MWC. The use of GCP can minimize CDD/CDF and HC emissions, including CDD/CDF precursors, by complete combustion of these pollutants. Current theory suggests that, following discharge from the combustor, CDD/CDF and volatile metal emissions can be further reduced by exhaust gas cooling, possibly by promoting condensation and adsorption of these pollutants onto particulates and subsequent removal by the PM control device. Furthermore, the data suggest that if MWC exhaust gases remain in the 480 to 600°F temperature region following discharge from the MWC, CDD/CDF can form downstream of the combustor. Therefore, exhaust gas cooling to 450°F or less is considered a part of GCP. Exhaust gas cooling can be achieved by water sprays, dilution air, or by the addition of heat exchanger surface area. All but one of the model plants have combustor exit temperatures of 450°F or less at baseline.

TABLE 2-1. SUMMARY OF NUMBER OF FACILITIES AND NUMBER OF COMBUSTORS SUBJECT TO THE NSPS IN 5-YEAR PERIOD AFTER PROPOSAL

Combustor Type[a]	Model Plant No.	Model Plant Number of Combustors	Model Plant Total Plant Size, (tpd)	Subject to NSPS Number of Combustors	Subject to NSPS Number of Facilities
Small MB/WW	1	2	200	34	17
Medium MB/WW	2	2	800	14	7
Large MB/WW	3	3	2,250	24	8
MB/REF	4	2	500	6	3
MB/RC	5	3	1,050	9	3
RDF	6	4	2,000	20	5
RDF (cofired)	7	4	2,000	12	3
MI/EA	8	2	240	6	3
MI/SA (no heat recovery)	9	2	50	4	2
MI/SA	10	2	100	12	6
FBC (BB)	11	2	900	6	3
FBC (CFB)	12	2	900	6	3
			Total	153	63

[a] MB/WW = Mass burn/waterwall
MB/REF = Mass burn/refractory
MB/RC = Mass burn/rotary combustor
RDF = Refuse-derived fuel
MI/EA = Modular incinerator/excess air
MI/SA = Modular incinerator/starved air
FBC = Fluidized-bed combustor
BB = Bubbling bed
CFB = Circulating fluidized-bed

Particulate matter control through the use of ESP's is a common practice for existing MWC's. Available data suggest ESP's are effective for the control of PM and most metals, but achieve little or no control of CDD/CDF and acid gases. Exhaust gas cooling upstream of an ESP to 450°F or less will prevent formation of CDD/CDF across the ESP.

Dry sorbent injection (DSI) has been applied at several MWC's in the United States as well as in Japan and Europe. With DSI, powdered dry sorbent is injected into either the combustor furnace (generally limestone or lime) or into the combustor outlet duct (generally hydrated lime). A downstream ESP or FF is used to collect flyash as well as reacted and unreacted sorbent. Dry sorbent injection can reduce HCl and SO_2 emissions; at equal sorbent feed rates, acid gas emissions are lower for DSI systems followed by a FF than if an ESP is used due to additional removal that occurs across the filter cake. When DSI is applied in conjunction with exhaust gas cooling to 300°F or less, CDD/CDF reductions as well as increased acid gas removal are also achieved. Because of the additional acid gas removal, it is expected that most new MWC's using DSI will employ a FF. For this reason, the cost estimates for DSI systems applied to the model MWC's in this report assume a FF. For estimating model plant emissions, however, the design performance levels are achievable with a simple DSI system, flue gas cooling to 350°F, and either an ESP or a FF. A properly designed DSI system equipped with a FF and flue gas cooling to 300°F or less can achieve higher performance levels.

Spray dryer emission data from several MWC's show high CDD/CDF, HCl, and SO_2 removal efficiencies. A FF is most commonly used downstream for PM control and enhanced acid gas and metals control. A spray dryer/FF combination is used in the report to estimate the performance and cost for the most stringent control option. As noted above, recent information indicates that advanced sorbent injection systems (which include a reaction vessel) followed by FF may achieve similar control to spray dryer/FF systems and may have slightly lower costs; however, data on such systems are limited.

The baseline represents the level of control that would exist in the absence of additional Federal regulation of MWC's. For new MWC units, it is assumed that GCP and good PM control are already in place and represent baseline conditions. This assumes a PM emission level of 0.08 gr/dscf for units larger than 50 TPD capacity but smaller than 100 million Btu/hr heat input (about 270 TPD, assuming a refuse heating value of 4,500 Btu/lb) as required by 40 CFR 60, Subpart E and 0.05 gr/dscf for units larger than 100 million Btu/hr heat input as required by 40 CFR 60, Subpart Db. It is assumed new units smaller than the 50 TPD cutoff in Subpart E will not use add-on controls and will emit about 0.1 gr/dscf.

The four control technologies were combined to produce the three control options. They are presented below from the least to most stringent option with respect to pollutant emissions.

Option 1:

- good combustion practices
- no acid gas control
- best PM control (by ESP) (0.01 gr/dscf)

Option 2:

- good combustion control
- good acid gas control (dry sorbent injection)
- best PM control (by FF or ESP) (0.01 gr/dscf)

Option 3:

- good combustion control
- best acid gas control (spray dryer)
- best PM control (by FF) (0.01 gr/dscf)

2.3 METHODOLOGIES FOR COSTING BASELINE AND CONTROL OPTIONS

This section presents the methodology for costing the baseline and the three control options discussed in Section 2.2. Table 2-2 summarizes the control options to be costed for the 12 model plants. Capital and annual costs of both the combustor and air pollution control device (APCD) are presented in December 1987 dollars. A 10 percent interest rate and a 15-year economic life are assumed for both the combustors and APCD equipment. The procedures, cost bases, and equipment specifications used to estimate capital and annual operating costs associated with each control option in Table 2-2 are summarized in Appendix A and explained in more detail in a separate report

TABLE 2-2. SUMMARY OF CONTROL OPTIONS FOR NEW FACILITIES

Control Options	Baseline	Control Option 1	Control Option 2	Control Option 3
Good combustion practices	X	X	X	X
Good PM control	X			
Best PM control		X	X	X
Good acid gas control			X	
Best acid gas control				X
Temperature control	X[a]	X	X	X

[a] Only for 50 TPD modular/starved air plant (Model Plant No. 9).

concerning MWC cost procedures.[6] Emissions control efficiencies associated with each control option are based upon information contained in a separate report regarding post-combustion control technologies.[7]

Baseline costs include GCP, ESP's sized to achieve good PM control, and opacity and CO monitors installed at the ESP outlet for continuous monitoring. In addition, costs will also be provided for Model Plant No. 9 for reducing PM emissions from 0.1 to 0.08 gr/dscf. These costs are based on a sidestream ESP designed to remove 90 percent of the particulates from 22 percent of the total plant flue gas. Costs for Control Option 1 are identical to that for baseline, except that ESP costs are estimated for each model plant based on the application of best PM control (0.01 gr/dscf). Temperature control costs are estimated only for combustors without heat recovery (Model Plant No. 9 in Table 1-2) based on cooling the flue gas to 450°F using humidification.

Costs for Control Option 2 are estimated for dry lime injection, fabric filtration, and temperature control to 300°F. The dry hydrated lime injection system is designed to remove 40 and 80 percent of the inlet SO_2 and HCl emissions, respectively, based on a calcium-to-acid gas molar ratio of 2:1. A pulse-jet fabric filter is installed downstream of the dry sorbent injection system to remove flyash and sorbent to 0.01 gr/dscf based on a net air-to-cloth ratio of 4:1. A fabric filter is selected because of their more widespread use with acid gas control systems applied to MWC's. A humidification water spray chamber is added upstream of the lime injection system and fabric filter to provide flue gas cooling to 300°F. To ensure that both the acid gas reduction levels and the PM emission levels are achieved, the following continuous emission monitors (CEM's) are installed:

- HCl, SO_2, and O_2 CEM's at both the inlet and outlet of the acid gas control device (i.e., the inlet CEM's are installed before the dry lime injection nozzles and the outlet CEM's are installed at the outlet of the fabric filter).
- An opacity monitor at the outlet of the fabric filter; and
- A data reduction system.

For Control Option 3, a lime spray dryer followed by a fabric filter is used. The lime spray dryer is designed to remove 90 and 97 percent of SO_2 and HCl, respectively, from the flue gas leaving the combustor. Lime slurry is fed at a calcium-to-acid gas molar ratio of 2.5:1. The fabric filter is designed with a net air-to-cloth ratio of 4:1 to decrease the flyash and spent sorbent to 0.01 gr/dscf. The CEM's discussed for Control Option 2 also apply to this option.

Table 2-3 presents the design parameters for each of the control systems to be applied at each of the model plants. With the exception of the three modular combustor model plants (Model Plant Nos. 8, 9, and 10), APCD's are installed on each combustor. For the modular model plants, a single APCD system is installed downstream of a waste heat boiler. With the exception of Model Plant Nos. 9 and 10 at baseline, the APCD is sized to treat the total flue gas flow from the waste heat boiler. No APCD was applied to Model Plant No. 9 at baseline. In the case of Model Plant No. 10 at baseline, a sidestream ESP is installed to remove 90 percent of the particulates from 22 percent of the total plant flue gas to reduce PM emissions from 0.1 to 0.08 gr/dscf.

The pressure drops across the APCD's are estimated to be 0.5 inches of water for ESP's, 7 inches of water for dry lime injection and FF systems, and 12.5 inches of water for spray dryer and FF systems. It is assumed that the pressure drop across humidification chambers used for flue gas cooling is negligible. Ducting lengths for PM control and spray dryers for each model plant in Table 2-3 are based on information contained in a separate document regarding the costs of flue gas cleaning technologies.[8] For dry sorbent injection, duct length for flue gas humidification was added assuming the duct length for flue gas humidification is the same as that used for PM control. The APCD Capital costs for the 2,000 TPD RDF cofired plant (Model Plant No 7) are based on burning 100 percent of RDF. This provides the flexibility for the plant to burn 100 percent RDF and still meet the emission control levels of the various control options, because the APCD equipment is designed for this fuel.

TABLE 2-3. DESIGN PARAMETERS FOR NEW MWC MODEL PLANT CONTROL SYSTEMS

Parameter	Small MB/WW (No. 1)	Medium MB/WW (No. 2)	Large MB/WW (No. 3)	MB/REF (No. 4)	MB/RC (No. 5)	RDF (No. 6)	RDF Cofired (No. 7)	MI/EA (No. 8)	MI/SA (No Heat Rec.) (No. 9)	MI/SA (No. 10)	FBC/BB (No. 11)	FBC/BB (No. 12)
Plant capacity, TPD (1000 TPY)	200 (41.7)	800 (267)	2,250 (750)	500 (167)	1,050 (350)	2,000 (667)	2,000 (667)	240 (80)	50 (10.4)	100 (20.8)	900 (300)	900 (300)
- Number of Combustors	2	2	3	2	3	4	4	2	2	2	2	2
- Number of control systems	2	2	3	2	3	4	4	1	1	1	2	2
Baseline:												
ESP System[a]												
- Specific collection plate area, ft^2/1000 acfm	257	295	295	257	295	350	350	257	0[e,f]	593[f]	3:1[h]	3:1[h]
- Ducting length, ft[b]	60	150	200	60	150	150	150	250	0[e,f]	130	150	150
Best PM Control:												
ESP System[c]												
- Specific collection plate area, ft^2/1000 acfm	423	423	423	423	423	478	478	423	184[g]	184	3:1[h]	3:1[h]
- Duct length, ft[b]	60	150	200	60	150	150	150	250	140	130	150	150
Good Acid Gas Control:												
Dry Sorbent Injection/Fabric Filter (DSI/FF)[c,d]												
- Lime consumption, tons/yr	566	3,620	10,200	2,260	4,750	12,870	6,700	1,090	142	453	0	0
- Limestone consumption, tons/yr	0	0	0	0	0	0	0	0	0	0	6,010	11.010
- Water consumption, gpm	7.1	28.4	79.9	29.7	31.0	72.6	75.0	9.5	17.1	4.0	0	0
- Compressed air, scfm	80	319	897	317	357	823	856	105	29.7	43.8	400	400
- Duct length, ft[b]	180	450	600	180	450	450	450	550	230	310	150	150

Continued

TABLE 2-3 (CONCLUDED). DESIGN PARAMETERS FOR NEW MWC MODEL PLANT CONTROL SYSTEMS

Parameter	Small MB/WW (No. 1)	Medium MB/WW (No. 2)	Large MB/WW (No. 3)	MB/REF (No. 4)	MB/RC (No. 5)	RDF (No. 6)	RDF Cofired (No. 7)	MI/EA (No. 8)	MI/SA (No Heat Rec.) (No. 9)	MI/SA (No. 10)	FBC/BB (No. 11)	FBC/CFB (No. 12)
Best Acid Gas Control:												
Spray Dryer/Fabric Filter (SD/FF)[c,i]												
- Lime consumption, tons/yr	320	2,060	5,780	1,290	2,700	7,310	3,860	616	80	256	1,740	1,740
- Limestone consumption, tons/yr	0	0	0	0	0	0	0	0	0	0	8,010	8,010
- Water consumption, gpm	7.1	28.4	79.9	29.7	31.0	72.6	75.0	9.5	17.1	4.0	11.6	11.6
- Compressed air, scfm	80	319	897	317	357	823	856	105	29.7	43.8	380	380
- Duct length, ft[b]	120	300	400	120	300	300	300	300	160	180	300	300

[a] Good PM control: 0.08 gr/dscf at 7% O_2, 450°F for model plants 1, 4, 8, 9, and 10; 0.05 gr/dscf at 7% O_2, 450°F for model plants 2, 3, 5, 6, and 7; and 0.01 gr/dscf at 7% O_2 for model plants 11 and 12.

[b] Duct lengths for model plants 1 to 7, 9, and 11 and 12 are for each combustor. Duct lengths for Model Plants 8 and 10 are for total plant. Duct length in parentheses for model plant 9 represents duct needed to achieve particulate emission of 0.08 gr/dscf.

[c] Best PM control: 0.01 gr/dscf at 7% O_2, 450°F.

[d] For model plants 1 to 10, 40%, 80%, and 75% control of SO_2, HCl, and CDD/CDF, respectively; for model plant 11, 25%, 69%, and 71% control of SO_2, HCl, and CDD/CDF, respectively; and for model plant 12, 81%, 94%, and 86% control of SO_2, HCl, and CDD/CDF, respectively.

[e] Particulate emissions are uncontrolled at baseline. To control the plant particulate emission level to 0.08 gr/dscf, the SCA would be 593 ft^3/1000 acfm and the ducting length required would be 140 ft^2.

[f] This SCA is for a packaged ESP removing 90 percent of the particulates from 22 percent of the plant's flue gas. This ESP is designed specifically for small modular incinerators (less than 50 tpd). The other ESP's are field-constructed units.

[g] To cool the flue gas to 450°F, water is injected in the flue gas at a rate of about 15 gpm.

[h] The FBC model plants use a FF for PM control under baseline and Control Option 1 (best PM control). The gross air to cloth ratio for the FF system is 3:1.

[i] For model plants 1 to 10, 70%, 90%, and 99% control of SO_2, HCl, and CDD/CDF, respectively. For model plant 11, 75%, 88%, and 97% control of SO_2, HCl, and CDD/CDF, respectively; and for model plant 12, 99%, 88%, and 97% control of SO_2, HCl, and CDD/CDF, respectively.

3.0 MASS BURN MODEL PLANTS

Mass burn facilities account for approximately 32,000 TPD (about 60 percent) of the projected MWC capacity expected to be subject to the NSPS (54,000 TPD). This equates to an annual waste flow of 10 million tons/year. There are three main types of mass burn plants: waterwall, refractory, and rotary combustor. All three types combust waste without any preprocessing other than the removal of items too large to go through the feed system.

The majority (85 percent) of the mass burn units are expected to have waterwall furnaces. This equals a capacity of 27,000 TPD, or annual waste flow of 8.4 million tons/year. Approximately 10 percent (3,200 TPD capacity, 1 million tons/year waste flow) are expected to have rotary combustors, and about 5 percent (1,500 TPD capacity, 0.5 million tons/year waste flow) are projected to have refractory-walled furnaces.

3.1 MASS BURN/WATERWALL AND MASS BURN/REFRACTORY MODEL PLANTS

3.1.1 Description

As stated above, MB/WW and MB/REF combustors burn unprocessed waste. Typical units use hydraulic rams or pusher grate sections to push the refuse from the fuel chute onto the grate. The grates are designed to move the waste through the combustor and to promote complete combustion by agitation of the fuel bed. In the waterwall units, tubes are located in the walls of the furnaces for heat recovery. Refractory units have downstream waste heat boilers for heat recovery.

3.1.2 Selection of Model Plant Sizes and Operating Characteristics

Table 3-1 lists waterwall and refractory mass burn plants that were either recently built (startup after 1984) or are currently in the advanced planning or construction stage for which information on combustor type, size, and number is available. The facilities are listed in order of increasing combustor size. Although information is not available to classify these facilities as waterwall or refractory combustors, the majority of MB facilities are expected to be waterwall units. Figure 3-1 shows the distribution of combustor sizes for the waterwall and refractory mass burn units contained in Table 3-1. Figure 3-2 shows the facility distribution for all waterwall and refractory mass burn facilities either recently built or

TABLE 3-1. MASS BURN (WATERWALL AND REFACTORY) FACILITY INFORMATION[a]

EPA REG	CITY	STATE	COMBUSTOR TYPE	TOTAL PLANT CAPACITY (TPD)	# OF COMBUSTORS	UNIT SIZE (TPD)	CO-FIRING	HEAT RECOVERY	CONTROL TYPE	STARTUP DATE	REFERENCES
6	ST. TAMMANY PARISH (MANDEVILLE)	LA	MB	120	2	60		YES	DS/BH	1990	TELEPHONE CONTACT TO CITY 4/88
1	Claremont	NH	MB/OF	200	2	100		YES	DSI/BH	1987	CITY CURRENTS 10/87
5	Jackson	MI	MB/OF	200	2	100		YES	DS/BH	1987	WASTE AGE 11/87
2	WARREN COUNTY	NJ	MB/OF	400	2	200		YES	DS/BH	1989	CITY CURRENTS 10/87, MCILVAINE 2/88
2	HUDSON FALLS (WASHINGTON CO.)	NY	MB/OF	400	2	200		YES	DS/ESP	1990	WASTE AGE 11/87, CITY CURRENTS 10/87
5	Rochester	MN	MB	200	1	200		YES	ESP	1987	CITY CURRENTS 10/87, DIRECT CALL TO FACILITY 1/88
2	PENNSAUKEN	NJ	MB	500	2	250		YES		1990	CITY CURRENTS 10/87, MCILVAINE 2/88
2	HUNTINGTON (LONG ISLAND)	NY	MB	750	3	250		YES	DS/BH	1990	WASTE AGE 11/87, MCILVAINE 2/88
9	STANISLAUS CO.(CROWS LANDING)	CA	MB/OF	800	3	267		YES	DS/BH/NOX	1989	MCILVAINE 2/88, EPA REGION IX OFFICE 1/88
10	Marion County	OR	MB/OF	550	2	275		YES	SD/BH	1986	CITY CURRENTS 10/87
9	Commerce (Los Angeles Co.)	CA	MB/OF	300	1	300		YES	DS/BH	1987	CITY CURRENTS 10/87
3	Alexandria/Arlington	VA	MB/OF	975	3	325		YES	ESP	1987	CITY CURRENTS 10/87, EPA REGION III SUBMITTAL 2/88
6	Tulsa	OK	MB/OF	1125	3	375		YES	ESP	1986	CITY CURRENTS 10/87, EPA REGION VI SUBMITTAL
10	SPOKANE COUNTY, CITY	WA	MB/OF	800	2	400		NO	DS/BH	1990	WASTE AGE 11/87, MCILVAINE 2/88
8	Davis County	UT	MB	400	1	400		YES		1987	CITY CURRENTS 10/87
5	Savage	MN	MB/OF	900	2	450		YES	ESP	1985	EPA REGION V SUBMITTAL 2/88 , DIRECT CALL TO FACILITY 2/8
5	HENNEPIN COUNTY (MINNEAPOLIS)	MN	MB	1212	2	606		YES	DS/FF	1989	CITY CURRENTS 10/87, CALL TO MPCA 4/88
1	Millbury	MA	MB/OF	1500	2	750		YES	SD/ESP	1988	MCILVAINE 2/88, EPA REGION I SUBMITTAL 2/88
1	North Andover	MA	MB/OF	1500	2	750		YES	ESP	1985	CITY CURRENTS 10/86
1	Bridgeport	CT	MB	2250	3	750		YES	DS/BH	1988	MCILVAINE 2/88
2	BROOKLYN NAVY YARD	NY	MB	3000	4	750		YES		1992	DIRECT CALL TO FACILITY 1/88, MCILVAINE 2/88
9	SAN DIEGO (SANDER)	CA	MB/OF	2250	3	750		YES	DS/BH/NOX	1989	MCILVAINE 2/88, EPA REGION IX OFFICE 1/88
3	Baltimore (Resco)	MD	MB/OF	2250	3	750		YES	ESP	1985	CITY CURRENTS 10/87, WASTE AGE 11/87
3	FAIRFAX	VA	MB	3000	4	750		YES	DS/BH	1990	WASTE AGE 11/87, MCILVAINE 2/88
2	HEMPSTEAD	NY	MB	2250	3	750		YES	DS/BH	1989	CITY CURRENTS 10/87, WASTE AGE 11/87, MCILVAINE 2/88
6	PASADENA	TX	MB/OF	1540	2	770		YES	ESP	1988	EPA REGION VI OFFICE 2/88
1	WEST HAVERHILL	MA	MB/OF	1650	2	825		YES		1989	MCILVAINE 2/88
6	SAN ANTONIO (LEON CREEK)	TX	MB	1800	2	900			DS	1988	MCILVAINE 2/88

[a] Contains existing facilities built since 1985 and facilities in the advanced stages of planning.

MB = mass burn

MB/OF = mass burn/overfeed

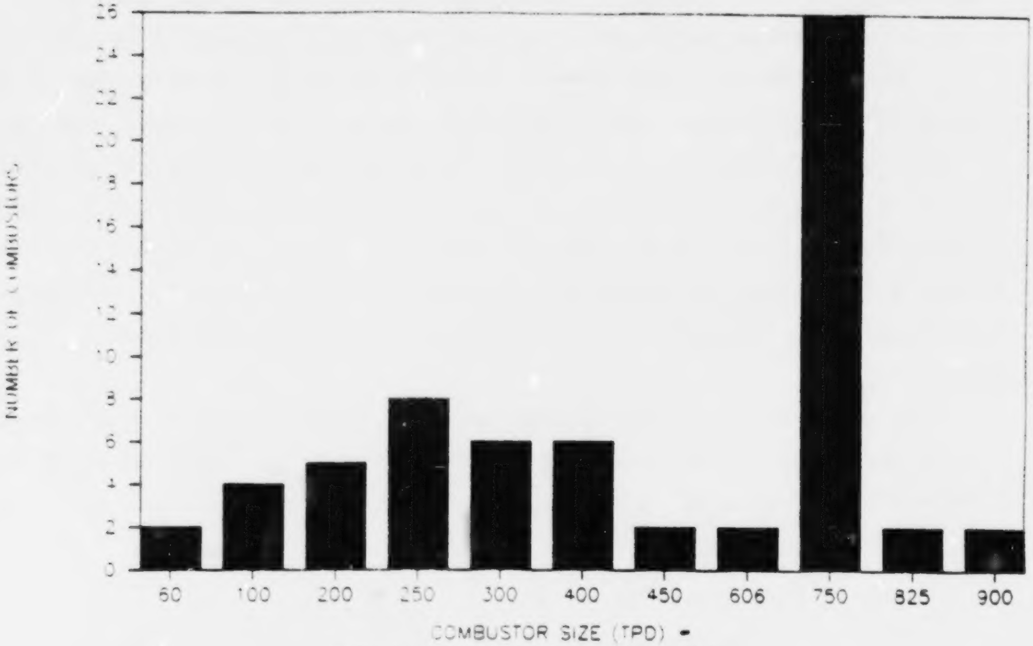

Figure 3-1. Mass burn combustor (waterwall and refactory) unit sizes.

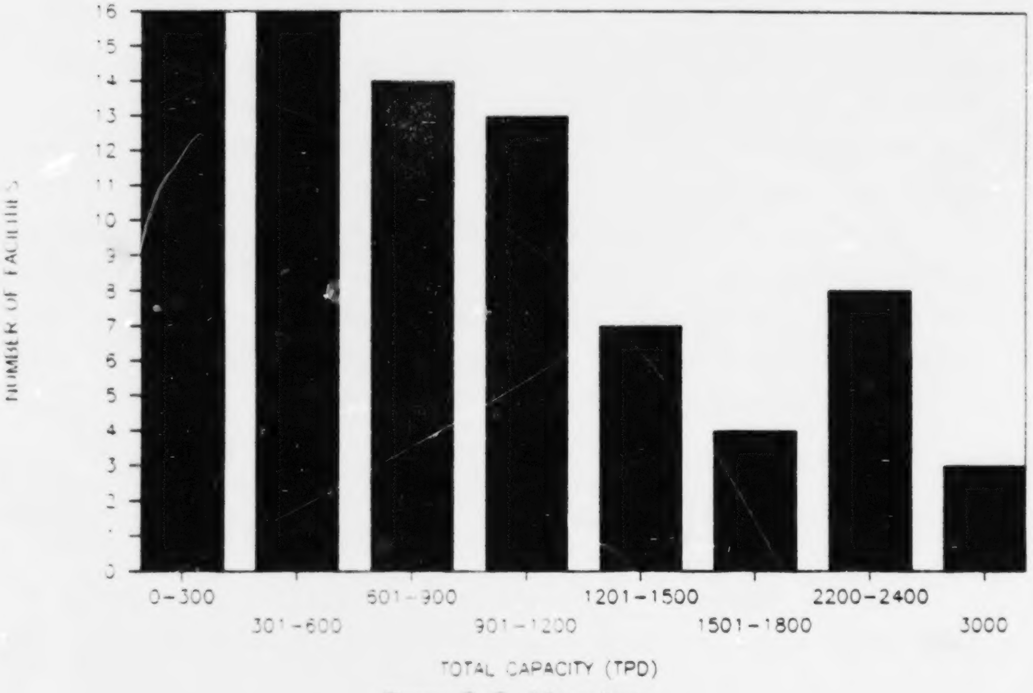

Figure 3-2. Mass burn (waterwall and refactory) facility sizes.

currently in the advanced planning or construction stage, even if facility-specific information on combustor size and number is not available.

Because of the large number and size distribution of projected mass burn waterwall combustors, three combustor size categories (small, medium, and large) were chosen to characterize the MB/WW facility population. Using the data in Table 3-1, these categories were defined as small (60-250 TPD), medium (267-606 TPD), and large (750-900 TPD). The small and medium size categories have 1 to 3 units per plant with 2 units being the median. The large combustor size category has 2 to 4 units per plant with a median value of 3 units.

From these data, representative model plants based on the typical number of combustors and combustor sizes were selected for each combustor size category. These model plants are as follows:

- 2 combustors at 100 TPD
- 2 combustors at 400 TPD
- 3 combustors at 750 TPD

Based solely on the distribution of combustor unit sizes presented in Figure 3-1, a combustor size of 200 TPD might have been selected to represent small facilities. However, the 100 TPD MB/WW model combustor size was selected to represent the smallest combustors, since there is particular interest in assessing the economic impacts of controls on small units. The 800 and 2,250 TPD model plants are representative of medium and large MB/WW facilities, respectively.

Since there are substantially fewer MB/REF plants than MB/WW projected and the size range is much narrower, one model plant is considered adequate to represent the MB/REF subcategory. Several manufacturers are building MB/REF units in the 150 to 500 TPD size range. Based on these data, the model plant selected to represent MB/REF plants is:

- 2 combustors at 250 TPD

3.1.3 Projected Number of Each Model Plant Subject to NSPS in 5-Year Period After Proposal

Considering the recently built and planned combustors in Table 3-1, on a total capacity basis, about 8 percent of total MB/WW capacity is represented by small combustors, 22 percent is represented by medium combustors, and 70 percent is represented by large combustors. Applying these percentages to total annual waste flow at MB/WW combustors (8.4 million tons/year) and dividing by the waste flow per model plant yielded the following estimates of number of combustors subject to the NSPS[4]:

- 17 plants (34 combustors) in the small size category (annual waste flow = 0.66 million tons/year)
- 7 plants (14 combustos) in the medium size category (annual waste flow = 1.8 million tons/year)
- 8 plants (24 combustors) in the large size category (annual waste flow = 5.9 million tons/year)

The projected MB/REF capacity of 1,500 TPD (waste flow of 0.5 million tons/year),[4] equates to 3 plants with a total of 6 combutors that are expected to be subject to the NSPS.

3.1.4 Model Plant Parameters

Table 3-2 lists the parameters for the MB/WW and MB/REF model plants. The table lists specifications for each model plant and emission estimates for PM, HCl, SO_2, CO, and total CDD/CDF on both a concentration and mass rate basis. The estimated uncontrolled PM, HCl, SO_2, CO, and total CDD/CDF emission rates are 2 gr/dscf, 500 ppmv, 200 ppmv, 50 ppmv, and 200 ng/dscm, respectively, for MB/WW units and 2 gr/dscf, 500 ppmv, 200 ppmv, and 100 ppmv, and 300 ng/dscm, respectively for MB/REF units. All flue gas concentrations are reported on a 7 percent O_2, dry basis. All of the MB/WW (except the 200 TPD plant) and MB/REF model plants are expected to operate 8,000 hours/yr and generate electricity. The 200 TPD MB/WW plant is expected to operate 5,000 hours/yr and have steam production only.

3.2 MASS BURN/ROTARY COMBUSTOR (WATER-COOLED) MODEL PLANT

3.2.1 Description

A mass burn/rotary combustor (MB/RC) consists of a rotary cylinder with alternating watertubes and perforated steel plates. Municipal solid waste (MSW) is metered into the combustor through a feed chute and ram feeder. Preheated combustion air enters the combustor through the perforated plates forming the walls of the cylinder. The combustor turns slowly and is oriented

TABLE 3-2. MASS BURN (WATERWALL AND REFRACTORY) MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

	Model Plants[a]			
Item	Small MB/WW (No. 1)	Medium MB/WW (No. 2)	Large MB/WW (No. 3)	MB/REF (No. 4)
Facility Specification				
No. of combustors per model	2	2	3	2
Total daily charge rate, TPD	200	800	2,250	500
Annual operating hours	5,000	8,000	8,000	8,000
Ash content of feed waste, %[b]	22.2	22.2	22.2	22.2
Excess combustion air, % of theoretical	80	80	80	200
PM emission factor, % of feed waste ash[b]	10	10	10	10
Baseline PM emission rate, gr/dscf:	0.08	0.05	0.05	0.08
Stack height, ft	140	200	230	150
Stack diameter, ft	4.0	6.0	7.0	9.0
Flue Gas Data Per Combustor[c]				
Volume flowrate:				
dscfm	11,500	46,000	86,200	48,100
scfm	13,300	53,100	99,500	52,500
acfm	22,800	91,100	171,000	90,200
Outlet temperature °F	450	450	450	450
Emission Concentrations per combustor at 7% O_2 (dry)[d]:				
Particulate Matter:				
gr/dscf	2	2	2	2
CO, ppmv	50	50	50	100
CDD/CDF, ng/dscm	200	200	200	300

(continued)

TABLE 3-2. MASS BURN (WATERWALL AND REFRACTORY) MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

	Model Plants[a]			
Item	Small MB/WW (No. 1)	Medium MB/WW (No. 2)	Large MB/WW (No. 3)	MB/REF (No. 4)
Acid gas:				
HCl, ppmv	500	500	500	500
SO_2, ppmv	200	200	200	200
Annual Emissions per combustor:[d]				
PM, tons/yr	408	2,610	4,890	1,630
CO, tons/yr	5	33	62	41
CDD/CDF (x10^{-2}), lbs/yr	3.56	22.8	42.8	21.4
HCl, tons/yr	69	439	823	274
SO_2, tons/yr	50	320	601	200

[a] MB/WW - mass burn/waterwall; MB/REF - mass burn/refractory.

[b] From Reference No. 8.

[c] Calculated based on the facility specifications in this table and the feed waste composition data from Table 1-3.

[d] Emissions at combustor exit. Annual emissions from the stack are included in Section 7.0. At baseline, stack emissions of PM are assumed to comply with the 0.05 gr/dscf or 0.08 gr/dscf limits as required by 40 CFR 60, Subparts Db or E. Baseline controls would not affect emissions of the other pollutants listed, and stack emissions would be the same as listed above.

with a slight downward tilt. The rotary section ends within a waterwall boiler allowing the residue to fall into an ash removal system.

3.2.2 Selection of Model Plant Sizes and Operating Characteristics

Table 3-3 lists the existing population of MB/RC plants built since 1985 and those in the advanced stages of planning for which information on combustor type, size, and number is available. Figure 3-3 presents the MB/RC size distribution from the information given in Table 3-3. Figure 3-4 shows the facility size distribution for all recently built (after 1984) facilities and those in the advanced planning or construction stages, even if facility-specific information on combustor size and number is not available. Since only about 10 percent of the total mass burn capacity is represented by rotary combustors, only one model plant is selected.

Although Table 3-3 shows a median combustor size of 300 TPD, the trend of recent sales of these units indicates that combustor sizes at newer plants are expected to be larger than at existing plants. The MB/RC unit sizes at the two facilities listed in Table 3-3 that are expected to startup in 1990 are about 350 TPD and 450 TPD; each facility has three combustors. Assuming these sizes and number of combustors per facility are indicative of newer plants, a 1,050 TPD plant consisting of three 350 TPD combustors was selected as the MB/RC model plant.

3.2.3 Projected Number of Each Model Plant Subject to NSPS in 5-Year Period After Proposal

As stated previously, approximately 10 percent (or 3,200 TPD) of the mass burn population is expected to be MB/RC. Dividing this capacity by the model plant size (1,050 TPD) and multiplying by the number of combustors per plant (3), yields a projection of 3 MB/RC plants with a total of 29 combustors subject to the NSPS.

3.2.4 Model Plant Parameters

Table 3-4 lists the parameters for the MB/RC model plant selected. The table lists specifications for the model plant and emission estimates for PM, HCl, SO_2, CO, and total CDD/CDF on both a concentration and mass rate basis. The estimated uncontrolled PM, HCl, SO_2, CO, and total CDD/CDF emission rates for MB/RC units are 2 gr/dscf, 500 ppmv, 200 ppmv, 100 ppmv, and 300 ng/dscm,

TABLE 3-3. MASS BURN/ROTARY COMBUSTOR FACILITY INFORMATION[a]

EPA REG	CITY	STATE	COMBUSTOR TYPE	TOTAL PLANT CAPACITY (TPD)	# OF COMBUSTORS	UNIT SIZE (TPD)	CO-FIRING	HEAT RECOVERY	CONTROL TYPE	STARTUP DATE	REFERENCES
10	SKAGIT COUNTY (MT. VERNON)	WA	MB/RC	178	2	89		YES	DS/BH	1988	WASTE AGE 11/87, MCILVAINE 2/88
4	Tampa	FL	MB/RC	1000	4	250		YES	ESP	1985	CITY CURRENTS 10/87
4	Panama City (Bay County)	FL	MB/RC	510	2	255		YES	ESP	1987	CITY CURRENTS 10/87
	SAN JUAN RR	PR	MB/RC	1040	3	347		YES	DS/BH	1990	MCILVAINE 2/88
2	Dutchess County (Poughkeepsie)	NY	MB/RC	400	1	400		YES	BH	1987	CITY CURRENTS 10/87
3	YORK CO. (MANCHESTER TNSHP)	PA	MB/RC	1344	3	448		YES	DS/BH	1990	CITY CURRENTS 10/87, WASTE AGE 11/87, MCILVAINE 2/88

[a] Contains existing facilities built since 1985 and facilities in the advanced stages of planning.

MB/RC = mass burn/rotary combustor

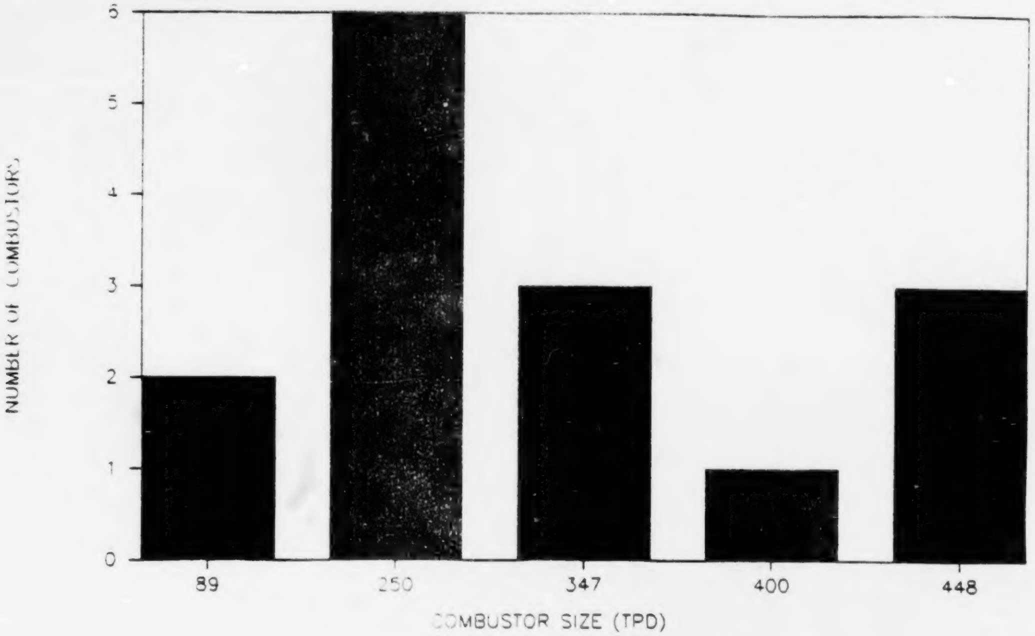

Figure 3-3. Mass/burn rotary combustor unit sizes.

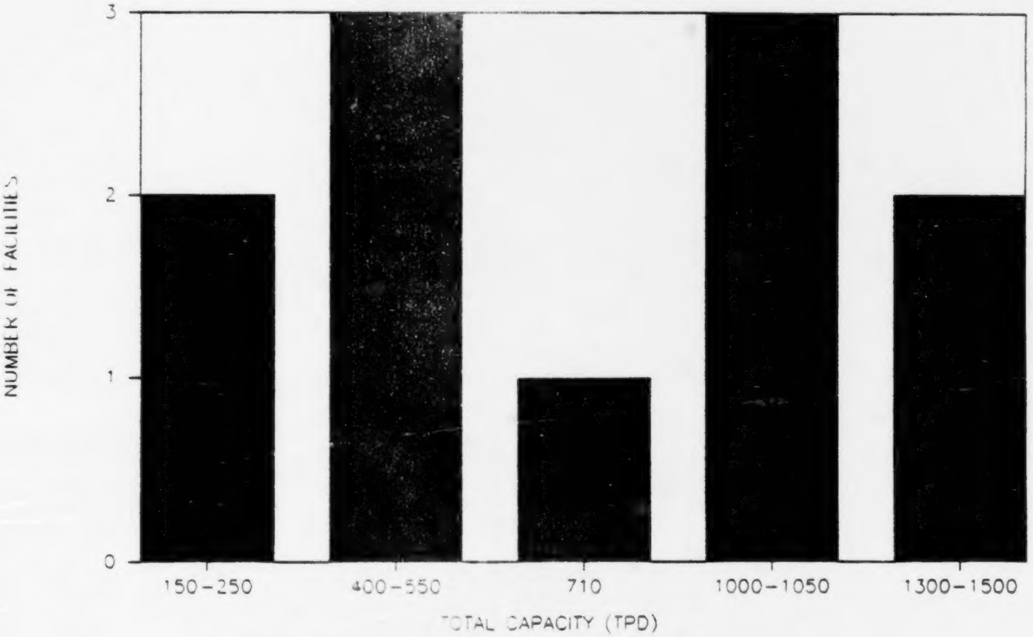

Figure 3-4. Mass/burn rotary facility sizes.

TABLE 3-4. MASS BURN/ROTARY COMBUSTOR MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model Plant[a] MB/RC (No. 5)
Facility Specification	
No. of combustors per model	3
Total daily charge rate, TPD	1,050
Annual operating hours	8,000
Ash content of feed waste, %[b]	22.2
Excess combustion air, % of theoretical[b]	50
PM emission factor, % of feed waste ash[b]	10
Baseline PM emission rate:	
gr/dscf	0.05
Stack height, ft	125
Stack diameter, ft	5.0
Flue Gas Data Per Combustor[c]	
Volume flowrate:	
dscfm	33,400
scfm	39,600
acfm	68,100
Outlet temperature °F	450
Emission Concentrations per combustor at 7% O_2 (dry)[d]:	
Particulate Matter, gr/dscf	2
CO, ppmv	100
CDD/CDF, ng/dscm	300
Acid gas:	
HCl, ppmv	500
SO_2, ppmv	200
Annual Emissions per combustor:[d]	
PM, tons/yr	2,280
CO, tons/yr	58
CDD/CDF ($\times 10^{-2}$), lbs/yr	29.8
HCl, tons/yr	383
SO_2, tons/yr	280

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[a] MB/RC - mass burn/rotary combustor.

[b] From Reference No. 8.

[c] Calculated based on the facility specifications in this table and the feed waste composition data from Table 1-3.

[d] Emissions at combustor exit. Annual emissions from the stack are included in Section 7.0. At baseline, stack emissions of PM are assumed to comply with the 0.05 gr/dscf limit as required by 40 CFR 60, Subpart Db. Baseline controls would not affect emissions of the other pollutants listed, and stack emissions would be the same as listed above.

TABLE 3-4. MASS BURN/ROTARY COMBUSTOR MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model Plant[a] MB/RC (No. 5)
Facility Specification	
No. of combustors per model	3
Total daily charge rate, TPD	1,050
Annual operating hours	8,000
Ash content of feed waste, %[b]	22.2
Excess combustion air, % of theoretical[b]	50
PM emission factor, % of feed waste ash[b]	10
Baseline PM emission rate:	
gr/dscf	0.05
Stack height, ft	125
Stack diameter, ft	5.0
Flue Gas Data Per Combustor[c]	
Volume flowrate:	
dscfm	33,400
scfm	39,600
acfm	68,100
Outlet temperature °F	450
Emission Concentrations per combustor at 7% O_2 (dry)[d]:	
Particulate Matter, gr/dscf	2
CO, ppmv	100
CDD/CDF, ng/dscm	300
Acid gas:	
HCl, ppmv	500
SO_2, ppmv	200
Annual Emissions per combustor:[d]	
PM, tons/yr	2,280
CO, tons/yr	58
CDD/CDF ($\times 10^{-2}$), lbs/yr	29.8
HCl, tons/yr	383
SO_2, tons/yr	280

[a] MB/RC - mass burn/rotary combustor.

[b] From Reference No. 8.

[c] Calculated based on the facility specifications in this table and the feed waste composition data from Table 1-3.

[d] Emissions at combustor exit. Annual emissions from the stack are included in Section 7.0. At baseline, stack emissions of PM are assumed to comply with the 0.05 gr/dscf limit as required by 40 CFR 60, Subpart Db. Baseline controls would not affect emissions of the other pollutants listed, and stack emissions would be the same as listed above.

respectively, reported on a 7 percent O_2, dry basis. The excess air level is 50 percent and the waste feed composition similar to that for MB/WW or refractory units. The MB/RC model plant is expected to operate 8,000 hours/yr and generate electricity.

4.0 REFUSE-DERIVED FUEL (RDF) MODEL PLANTS

4.1 DESCRIPTION

Processed municipal waste, regardless of the degree of processing performed, is broadly referred to as RDF. The degree of processing can vary from simple removal of bulky items accompanied by shredding, to extensive processing to produce a finely divided fuel suitable for cofiring in pulverized coal-fired boilers. The general types of boilers used to combust RDF can include suspension, stoker, and fluidized-bed designs.

4.2 SELECTION OF MODEL PLANT SIZE AND OPERATING CHARACTERISTICS

Figure 4-1 shows information on facility sizes for all RDF plants (20 facilities) that were either recently built (startup after 1984) or are currently in the advanced planning or construction stage. As is shown in Figure 4-1, the majority of the RDF plants are between 1,000 and 2,000 TPD. Table 4-1 presents information for the four existing plants for which data on combustor type, size, and number are available. Figure 4-2 shows the combustor size distribution for these plants. From the information in Table 4-1, individual combustors at these plants form a relatively narrow size range of 250 to 500 TPD RDF, and the plants generally have two to four combustors.

Therefore, due to the narrow range in combustor and plant size, only one model plant was selected to represent this subset of the MWC industry. As shown in Figure 4-1 compared to Table 4-1, the newer facilities are generally larger than existing facilities. Therefore, the combustor size and number of combustors for the model plant were selected at the high end of the range for the available data (i.e., 500 TPD capacity and four combustors). Therefore, the following model plant was selected:

o 4 combustors at 500 TPD each

In addition, since some RDF plants cofire multiple fuels, another model plant was selected to represent a cofired facility. This model plant is identical to the model above except that it fires a 50/50 mixture (on a mass basis) of RDF and wood. Wood was selected because it is the most common fuel cofired in existing RDF units.

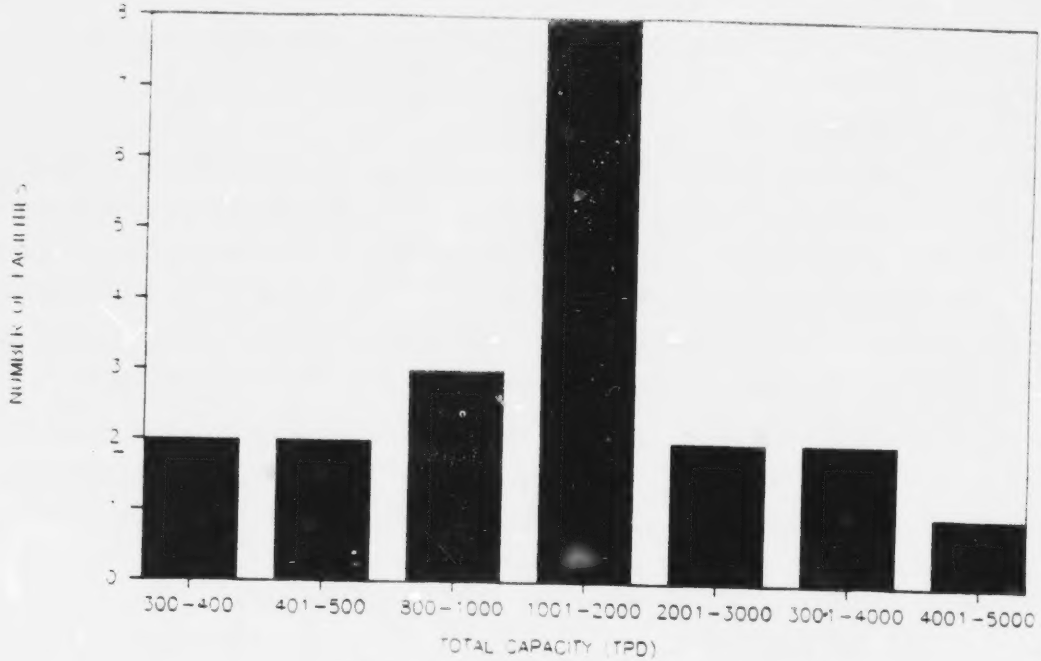

Figure 4-1. RDF facility sizes.

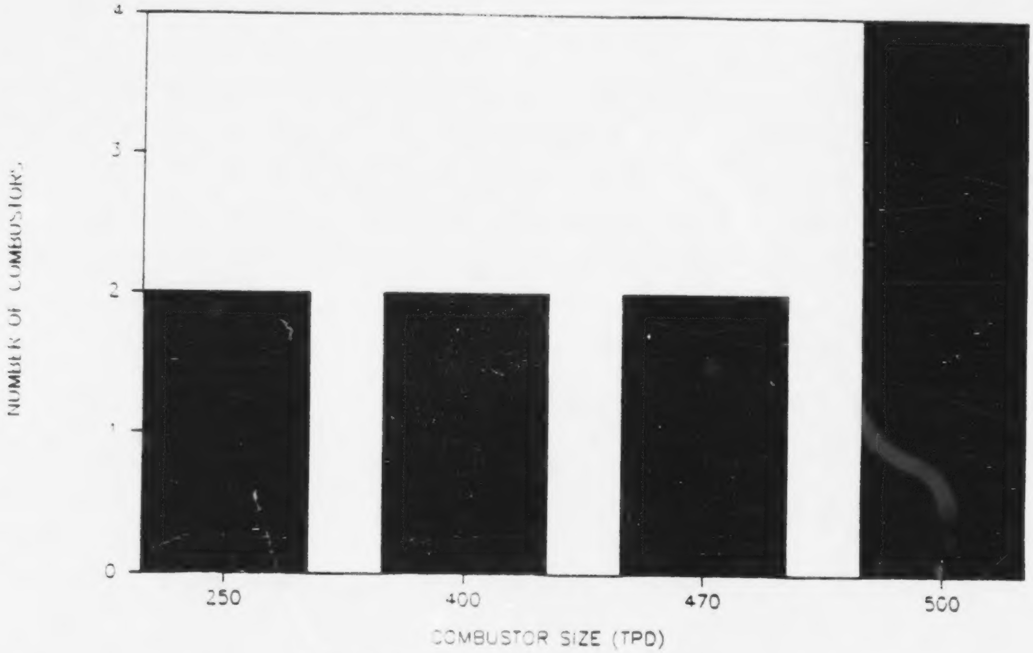

Figure 4-2. RDF combustor unit sizes.

TABLE 4-1. RDF FACILITY INFORMATION[a]

EPA REG	CITY	STATE	COMBUSTOR TYPE	TOTAL PLANT CAPACITY (TPD)	# OF COMBUSTORS	UNIT SIZE (TPD)	CO-FIRING	HEAT RECOVERY	CONTROL TYPE	STARTUP DATE	REFERENCES
1	Biddeford/Saco	ME	RDF	500	2	250	WOOD/OIL/SLUDGE	YES	DS/BH	1987	CITY CURRENTS 10/87, WASTE AGE 11/87, TRIP REPORT 2/88
1	BANGOR (PERC) (ORRINGTON)	ME	RDF	800	2	400	WOOD	YES	DS/BH	1988	DIRECT CALL TO FACILITY 3/88
5	Mankato	MN	RDF	940	2	470		YES	ESP	1987	DIRECT CONTACT TO CITY 1/88
3	Portsmouth (Norfolk Navy Yard)	VA	RDF	2000	4	500	COAL	YES	ESP	1988	CITY CURRENTS 10/87, EPA REGION III SUBMITTAL 3/88

[a] All units are existing.

RDF = refuse-derived fuel

4.3 PROJECTED NUMBER OF EACH MODEL PLANT SUBJECT TO NSPS IN 5-YEAR PERIOD AFTER PROPOSAL

Refuse-derived fuel plants account for 27 percent (33,300 TPD) of the total design capacity for NSPS plants (16,000 TPD capacity, 4.2 million tons/year total MSW flow). Based on the percentage of existing and projected RDF facilities that cofire fuels, it is assumed 35 percent of the new plants will cofire and 65 percent will fire RDF only. Dividing this by the model plant and combustor sizes of 2,000 TPD and 500 TPD, respectively, yields 3 cofired RDF plants with a total of 12 combustors and 5 non-cofired RDF plants with a total of 20 combustors subject to the NSPS in the 5-year period after proposal.

4.4 MODEL PLANT PARAMETERS

The parameters for the two RDF model plants are listed in Table 4-2. The table lists specifications for each model plant and emission estimates for PM, HCl, SO_2, CO, and total CDD/CDF on both a concentration and mass rate basis.

The estimated uncontrolled PM, HCl, SO_2, CO, and total CDD/CDF emission rates for the RDF model plant are 4 gr/dscf, 500 ppmv, 300 ppmv, 100 ppmv, and 1000 ng/dscm, respectively. Uncontrolled estimates of PM, HCl, SO_2, CO, and total CDD/CDF emission rates for the RDF cofired model plant are 4 gr/dscf, 250 ppmv, 150 ppmv, 100 ppmv, and 1000 ng/dscm, respectively. All flue gas concentrations are reported on a 7 percent O_2, dry basis. The higher particulate rates from RDF facilities are due to the more concentrated fuel. The excess air level for the RDF and RDF cofired model plant is 50 percent. The waste feed composition for the RDF/wood mixture was calculated by averaging the ultimate analysis compositions of RDF and wood. Both RDF model plants are expected to operate 8,000 hours/yr and generate electricity.

TABLE 4-2. RDF MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model Plants[a] RDF (No.6)	Model Plants[a] RDF Cofired (No. 7)
Facility Specification		
No. of combustors per model	4	4
Total daily charge rate, TPD	2,000	2,000
Annual operating hours	8,000	8,000
Ash content of feed waste, %[b]	7.5	4.3
Excess combustion air, % of theoretical[b]	50	50
PM emission factor, % of feed waste ash[b]	80	80
Baseline PM emission rate, gr/dscf	0.05	0.05
Stack height, ft	200	200
Stack diameter, ft	8.0	8.0
Flue Gas Data Per Combustor[c]		
Volume flowrate:		
dscfm	58,700	52,000
scfm	68,500	62,600
acfm	118,000	107,000
Outlet temperature °F	450	450
Emission Concentrations per combustor at 7% O_2 (dry)[d]:		
Particulate Matter, gr/dscf	4	4
CO, ppmv	100	100
CDD/CDF, ng/dscm	1000	1000
Acid gas:		
HCl, ppmv	500	250
SO_2, ppmv	300	150
Annual Emissions per combustor:[d]		
PM, tons/yr	8,030	7,130
CO, tons/yr	102	90
CDD/CDF ($\times 10^{-2}$), lbs/yr	176	156
HCl, tons/yr	669	326
SO_2, tons/yr	666	368

[a] RDF - refuse-derived fuel.

[b] From Reference No. 8.

[c] Calculated based on the facility specifications in this table and the feed waste composition data from Table 1-3.

[d] Emissions at combustor exit. Annual emissions from the stack are included in Section 7.0. At baseline, stack emissions of PM are assumed to comply with the 0.05 gr/dscf limit as required by 40 CFR 60, Subpart Db. Baseline controls would not affect emissions of the other pollutants listed, and stack emissions would be the same as listed above.

5.0 MODULAR MODEL PLANTS

5.1 MODULAR/EXCESS AIR

5.1.1 Description

Similar to mass burn units, modular combustors also burn waste without preprocessing, but are usually smaller and have two combustion chambers. In the excess air design, primary combustion air is supplied in excess of the stoichiometric amount required for complete combustion. No additional air is added to the secondary chamber, it simply provides additional residence time for the completion of combustion. This is functionally similar to larger mass burn units.

5.1.2 Selection of Model Plant Size and Operating Characteristics

Table 5-1 lists existing MI/EA plants built since 1985 and those in advanced planning or construction stages for which information on combustor type, size, and number is available. Figure 5-1 shows the combustor size distribution for the information given in Table 5-1. Figure 5-2 shows the facility size distribution for all MI/EA facilities either recently built (startup after 1984) or in the advanced planning or construction stages, even if facility-specific information on combustor size and number is not available. As indicated in Table 5-1, most of the plants have two or three combustors and most of the combustor sizes are between 100 and 140 TPD. Based on this information, a model plant was selected to be representative of MI/EA facilities. The selected model plant consists of:

- 2 combustors at 120 TPD

5.1.3 Projected Number of Each Model Plant Subject to NSPS in 5-Year Period After Proposal

The total projected capacity of modular incinerators is 1,400 TPD, or a waste flow of 1 million tons/year.[4] Of this capacity, approximately half (700 TPD) is expected to be of the excess air design based on current projections. Dividing the estimated MI/EA capacity of 700 TPD by the MI/EA model plant capacity (240 TPD) and multiplying by the number of combustors per model plant, yields a projection of 3 plants with a total of 6 combustors that are subject to the NSPS.

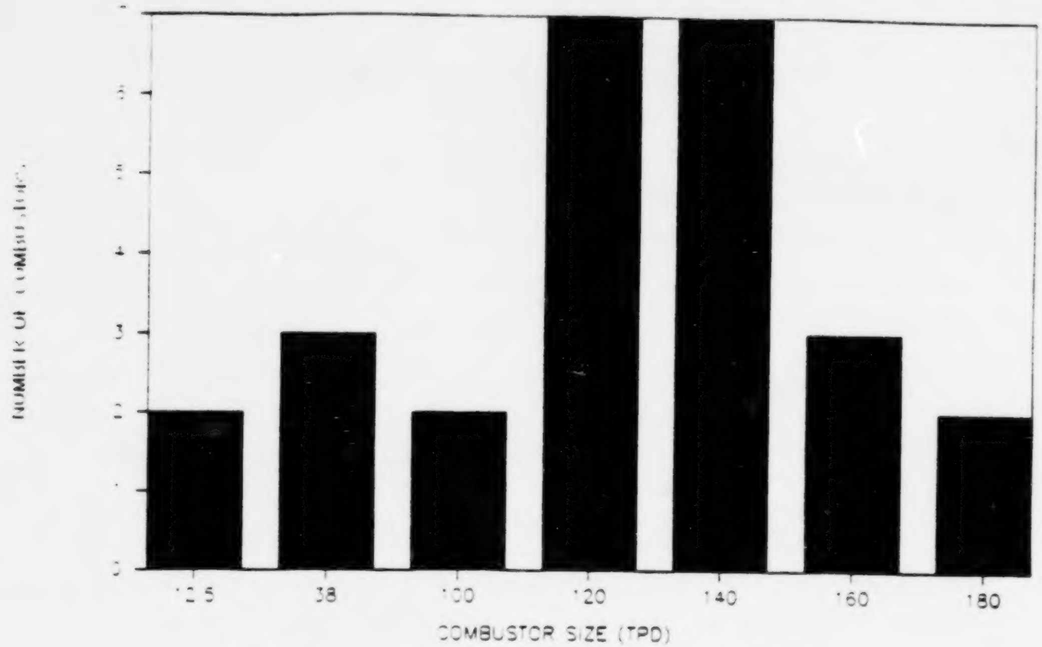

Figure 5-1. Modular/excess air combustor unit sizes.

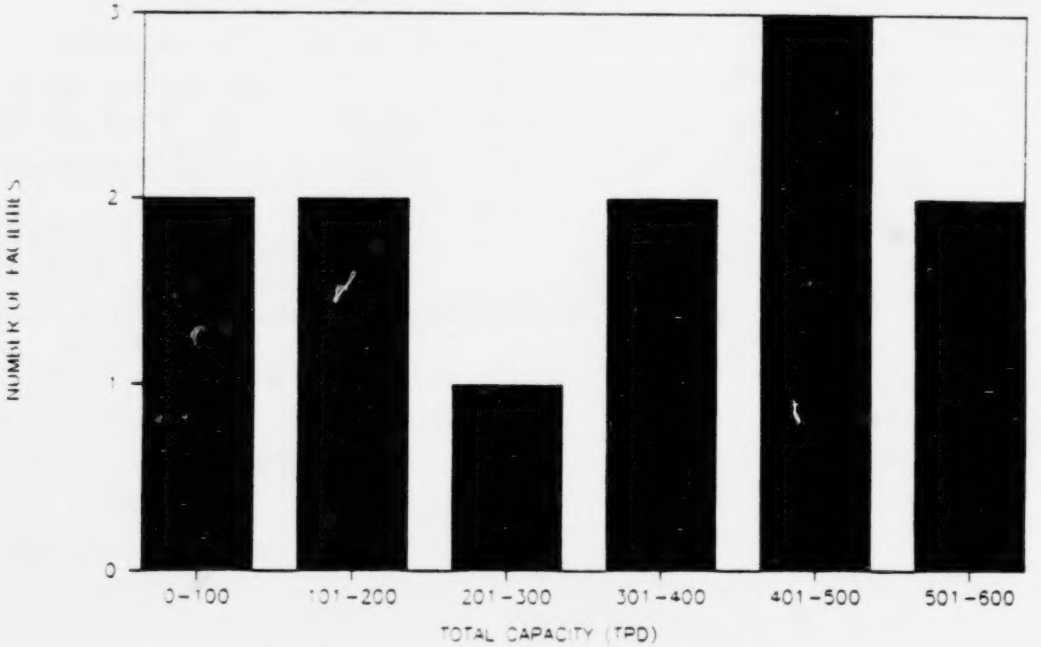

Figure 5-2. Modular/excess air facility sizes.

TABLE 5-1. MODULAR/EXCESS AIR FACILITY INFORMATION[a]

EPA REG	CITY	STATE	COMBUSTOR TYPE	TOTAL PLANT CAPACITY (TPD)	# OF COMBUSTORS	UNIT SIZE (TPD)	CO-FIRING	HEAT RECOVERY	CONTROL TYPE	STARTUP DATE	REFERENCES
10	Sitka	AK	MI/EA	25	2	12.5		YES	ESP	1985	CITY CURRENTS 10/87, DIRECT CALL TO FACILITY 1/88
6	Cleburne	TX	MI/EA	115	3	38		YES	ESP	1986	STATE OF TEXAS, CITY CURRENTS 10/87
10	Bellingham	WA	MI/EA	100	1	100		YES	NONE	1986	WASTE AGE 11/87, CITY CURRENTS 10/87
5	Alexandria (Pope/Douglas Co.)	MN	MI/EA	103	1	103		YES	ESP	1986	DIRECT CONTACT TO FACILITY 1/88, CITY CURRENTS 10/87, MPCA SUBMITTAL 3/31/88
1	Rutland	VT	MI/EA	220	2	110		YES	ESP	1987	CITY CURRENTS 10/87
3	Wilmington (Pigeon Point)	DE	MI/EA	600	5	120		YES	ESP	1987	EPA REGION III SUBMITTAL 2/88, WASTE AGE 11/87
1	WALLINGFORD	CT	MI/EA	420	3	140		YES	DS/BH	1989	MCILVAINE 2/88, DIRECT CALL TO CITY 1/88
1	MANCHESTER	NH	MI/EA	560	4	140		YES		1990	MCILVAINE 2/88, EPA REGION I OFFICE 1/88
1	SPRINGFIELD	MA	MI/EA	480	3	160		YES	DS/BH	1988	MCILVAINE 2/88
1	WE[illegible]	MA	MI/EA	360	2	180		YES		1989	MCILVAINE 2/88

[a]Contains existing facilities built since 1985 and facilities in the advanced stages of planning.

MI/EA = modular/excess air

5.1.4 Model Plant Parameters

The plant parameters for the MI/EA model plant are listed in Table 5-2. The table lists specifications for the model plant and emission estimates for PM, HCl, SO_2, CO, and total CDD/CDF on both a concentration and mass rate basis.

The uncontrolled PM, HCl, SO_2, CO, and total CDD/CDF emission rates for MI/EA combustors are 2 gr/dscf, 500 ppmv, 200 ppmv, 100 ppmv, 200 ng/dscm, respectively, reported on a 7 percent O_2, dry basis. The excess air level is 100 percent and the waste feed composition is similar to the mass burn units. The MI/EA model plant is expected to operate 8,000 hours/yr and generate electricity.

5.2 MODULAR/STARVED AIR

5.2.1 Description

The MI/SA combustors are similar to the excess air units except that excess air is introduced at substoichiometric levels in the primary chamber. The lower air velocity in the primary combustion chamber minimizes entrainment of fuel particles and ash in the flue gas. The incomplete combustion products then pass into a secondary combustion chamber where excess air is added and combustion is completed.

5.2.2 Selection of Model Plant Sizes and Operating Characteristics

Table 5-3 lists the existing MI/SA plants built since 1985 and those in the advanced planning or construction stages for which information on combustor type, size, and number is available. Although MI/SA plants represent only a small subset of the MWC industry by capacity, they represent approximately six percent of all planned MWC facilities. Figure 5-3 presents the combustor unit size distribution for the information in Table 5-3. Figure 5-4 shows all facilities either recently built or in the advanced planning or construction stages, even if facility-specific information on combustor size and number is not available. As can be seen from comparing Figures 5-1 and 5-3, MI/SA combustors tend to be smaller in size than the MI/EA combustors, with the most common MI/SA combustor size being 50 TPD.

TABLE 5-2. MODULAR/EXCESS AIR MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model Plant[a] MI/EA (No. 8)
Facility Specification	
No. of combustors per model	2
Total daily charge rate, TPD	240
Annual operating hours	8,000
Ash content of feed waste, %[b]	22.2
Excess combustion air, % of theoretical[b]	100
PM emission factor, % of feed waste ash[b]	0.50
Baseline PM emission rate, gr/dscf	0.08
Stack height, ft	70
Stack diameter, ft	6.0
Flue Gas Data Per Combustor[c]	
Volume flowrate:	
dscfm	15,300
scfm	17,500
acfm	30,000
Outlet temperature °F	450
Emission Concentrations per combustor at 7% O_2 (dry)[d]:	
Particulate Matter, gr/dscf	2
CO, ppmv	100
CDD/CDF, ng/dscm	200
Acid gas:	
HCl, ppmv	500
SO_2, ppmv	200
Annual Emissions per combustor:[d]	
PM, tons/yr	783
CO, tons/yr	22
CDD/CDF ($\times 10^{-2}$), lbs/yr	6.84
HCl, tons/yr	132
SO_2, tons/yr	96

[a] MI/EA - modular/excess air.

[b] From Reference No. 8.

[c] Calculated based on the facility specifications in this table and the feed waste composition data from Table 1-3.

[d] Emissions at combustor exit. Annual emissions from the stack are included in Section 7.0. At baseline, stack emissions of PM are assumed to comply with the 0.08 gr/dscf limit as required by 40 CFR 60, Subpart E. Baseline controls would not affect emissions of the other pollutants listed, and stack emissions would be the same as listed above.

TABLE 5-3. MODULAR/STARVED AIR FACILITY INFORMATION[a]

EPA REG	CITY	STATE	COMBUSTOR TYPE	TOTAL PLANT CAPACITY (TPD)	# OF COMBUSTORS	UNIT SIZE (TPD)	CO-FIRING	HEAT RECOVERY	CONTROL TYPE	STARTUP DATE	REFERENCES
6	Center	TX	MI/SA	36	1	36		YES	NONE	1985	STATE OF TEXAS, DIRECT CALL TO CITY 1/88
6	Carthage City	TX	MI/SA	36	1	36		YES	NONE	1985	STATE OF TEXAS, CITY CURRENTS 10/87
5	Perham (Quadrant)	MN	MI/SA	75	2	37.5		YES	ESP	1987	WASTE AGE 11/87, CITY CURRENTS 10/87, MPCA SUBMITTAL 3/31/88
5	Barron County	WI	MI/SA	80	2	40		NO	ESP	1986	STATE OF WISCONSIN, WASTE AGE 11/87
5	Fosston (Polk Co.)	MN	MI/SA	90	2	45		YES	ESP	1988	WASTE AGE 11/87, DIRECT CONTACT TO COUNTY 1/88
10	Bellingham	WA	MI/SA	100	2	50		YES	NONE	1986	WASTE AGE 11/87, CITY CURRENTS 10/87
2	Oswego County (Volney)	NY	MI/SA	200	4	50		YES	ESP	1986	CITY CURRENTS 10/87
3	Greensburg (Westmoreland Co.)	PA	MI/SA	50	1	50		YES		1987	CITY CURRENTS 10/87
2	Oneida Co. (Rome)	NY	MI/SA	200	4	50		YES	ESP	1985	CITY CURRENTS 10/87
4	Pascagoula	MS	MI/SA	150	2	75		YES	ESP	1985	CITY CURRENTS 10/87
4	Hampton	SC	MI/SA	270	3	90		YES	ESP	1985	CONSUMAT, WASTE AGE 11/87
3	Edgewood (Harford County)	MD	MI/SA	360	4	90		YES	ESP	1987	EPA REGION III SUBMITTAL 2/88 , WASTE AGE 11/87

[a] Contains existing facilities built since 1985 and facilities in the advanced stages of planning.

MI/SA = modular/starved air

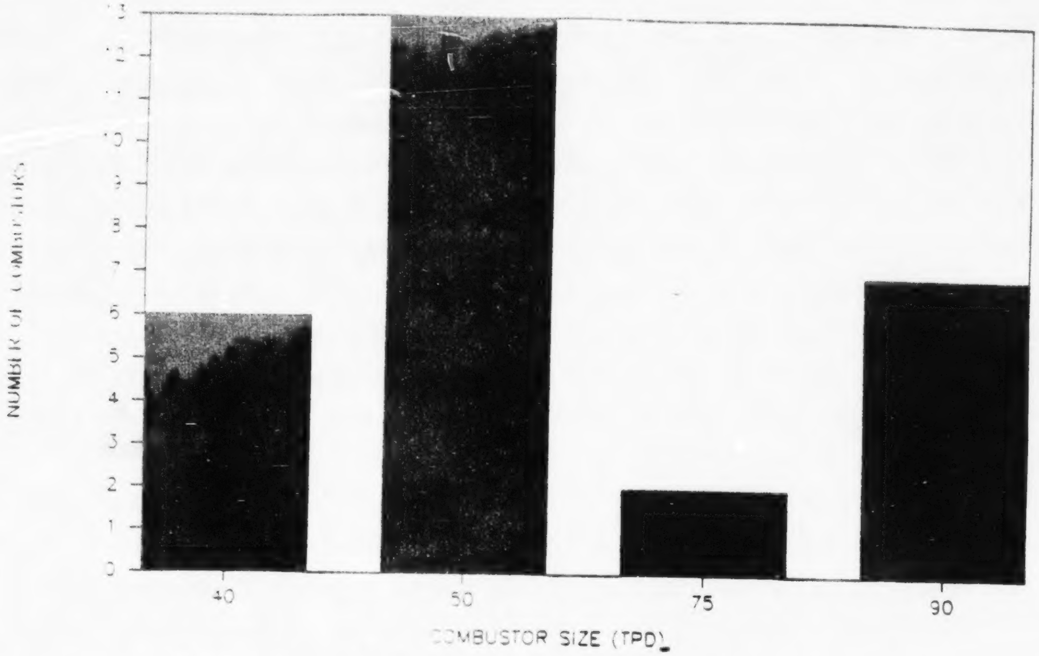

Figure 5-3. Modular/starved air combustor unit sizes.

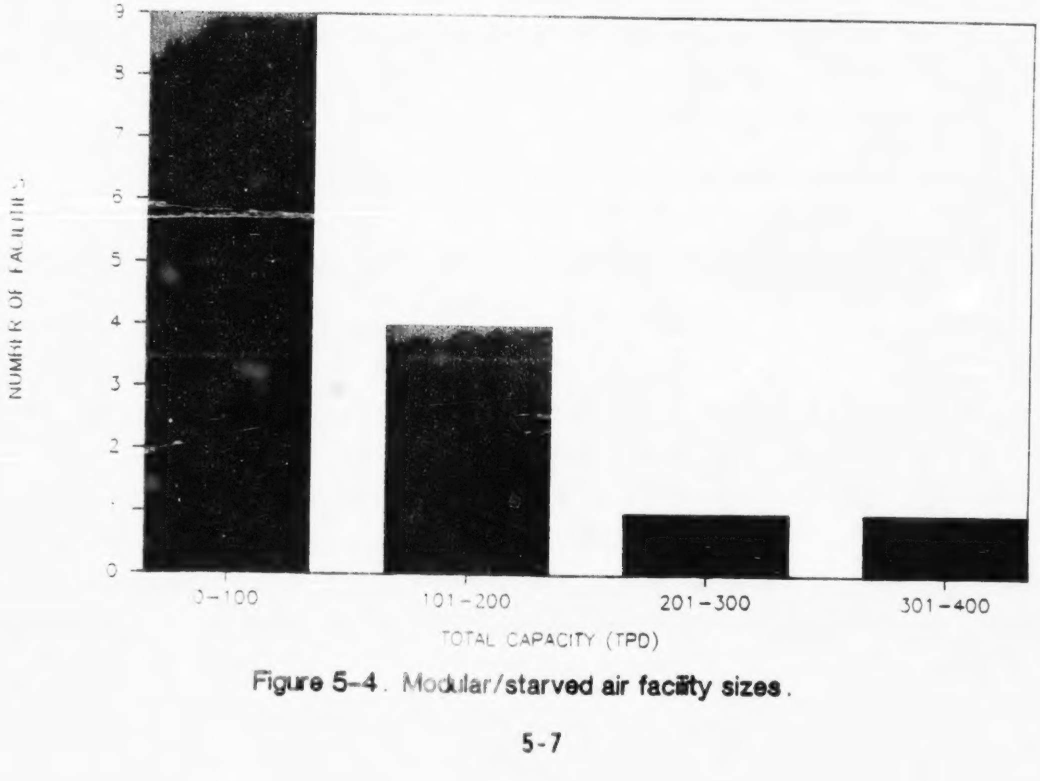

Figure 5-4. Modular/starved air facility sizes.

MI/SA plant capacities are also smaller than MI/EA plants with a median MI/SA plant size near 100 TPD. The number of combustors per plant ranges from one to four, with two combustors being the most common.

As is shown in Table 5-3, almost all of the recently built facilities have heat recovery. However, information from a major MI/SA manufacturer indicates that approximately half of the smaller MI/SA plants to be built in the next several years will not have heat recovery.[9] Therefore, two MI/SA model plants were selected, one of which does not employ heat recovery and one which does. This will allow differentiation between small plants that do not realize the economic benefit of producing steam or electricity and simply burn the waste to reduce landfill costs.

Based on the finding that 50 TPD is the most common combustor size and that two combustors per plant is common, the model plant selected to represent the MI/SA facility that employs heat recovery consists of two combustors at 50 TPD each for a total plant capacity of 100 TPD. Since the facilities that do not employ heat recovery are expected to be smaller in size than the facilities that employ heat recovery, two combustors at 25 TPD each were selected as the model plant that does not employ heat recovery. This is at the low end of the combustor and plant size ranges but will allow estimation of impacts for the smallest plants expected to be built for this category of MWC's.

The model plants selected are:

- 2 combustors at 25 TPD, no heat recovery; and
- 2 combustors at 50 TPD, with heat recovery.

5.2.3 Projected Number of Each Model Plant Subject to NSPS in 5-Year Period After Proposal

As is shown in Table 5-3, three of the twelve facilities (25 percent) are small (≤ 75 TPD) and the remainder of the facilities (75 percent) are large. On the basis of total capacity, small plants represent only 9 percent of the total capacity (150 TPD out of 1,650 TPD total capacity for plants in Table 5-3). Dividing the projected MI/SA capacity of 700 TPD by the combustor size and multiplying by the number of combustors per model plant yields 2 small plants (with a total of 4 combustors) without heat recovery and 6 large plants (with a total of 12 combustors) with heat recovery which are subject to the NSPS.

5.2.4 Model Plant Parameters

Table 5-4 presents the parameters for both of the MI/SA model plants. The table lists specifications for each model plant and emission estimates for PM, HCl, SO_2, CO, and total CDD/CDF on a concentration and mass rate basis. Uncontrolled estimates of PM, HCl, SO_2, CO, and total CDD/CDF emission rates for both MI/SA model plants are 0.1 gr/dscf, 500 ppmv, 200 ppmv, 50 ppmv, 300 ng/dscm, respectively, reported on a 7 percent O_2, dry basis. An excess air level of 100 percent was used; the waste feed composition was similar to that for mass burn units. The 50 TPD MI/SA model plant is expected to operate 5,000 hours/yr and have no heat recovery. The 100 TPD MI/SA model plant is expected to operate 8,000 hours/yr and generate electricity.

TABLE 5-4. MODULAR/STARVED AIR MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model Plants[a] MI/SA no heat rec. (No. 9)	Model Plants[a] MI/SA (No. 10)
Facility Specification		
No. of combustors per model	2	2
Total daily charge rate, TPD	50	100
Annual operating hours	5,000	8,000
Ash content of feed waste, %[b]	22.2	22.2
Excess combustion air, % of theoretical[b]	100	100
PM emission factor, % of feed waste ash[b]	0.50	0.50
Baseline PM emission rate, gr/dscf	0.1	0.08
Stack height, ft	60	60
Stack diameter, ft	5.0	5.0
Flue Gas Data Per Combustor[c]		
Volume flowrate:		
dscfm	3,200	6,400
scfm	3,600	7,300
acfm	14,100	12,500
Outlet temperature °F	1,600	450
Emission Concentrations per combustor at 7% O_2 (dry)[d]:		
Particulate Matter, gr/dscf	0.1	0.1
CO, ppmv	50	50
CDD/CDF, ng/dscm	300	300
Acid gas:		
HCl, ppmv	500	500
SO_2, ppmv	200	200
Annual Emissions per combustor:[d]		
PM, tons/yr	5	16
CO, tons/yr	2	4
CDD/CDF ($x10^{-2}$), lbs/yr	1.34	4.28
HCl, tons/yr	17	55
SO_2, tons/yr	13	40

[a] MI/SA - modular/starved air.

[b] From Reference No. 8.

[c] Calculated based on the facility specifications in this table and the feed waste composition data from Table 1-3.

[d] Emissions at combustor exit. Annual emissions from the stack are included in Section 7.0. At baseline, stack emissions of PM for Model Plant 10 are assumed to comply with the 0.08 gr/dscf limit as required by 40 CFR 60, Subpart E. Model Plant 9 is below the size cutoff for Subpart E and is not expected to have air pollution control at baseline. Baseline controls would not affect emissions of the other pollutants listed, and stack emissions would be the same as listed above.

6.0 FLUIDIZED-BED COMBUSTION (FBC) MODEL PLANTS

6.1 DESCRIPTION

With FBC, the waste burns in a turbulent bed of heated noncombustible material, such as limestone, sand, silica, or alumina. Typical bed temperatures are 1,450 to 1,700°F. As with conventional combustors, primary combustion air is introduced underneath the bed, but at a flowrate high enough to suspend or "fluidize" the solid particles in the bed. The ability to achieve good fluidization depends on the uniformity of fuel particle size and density produced during fuel preprocessing. Secondary combustion air is introduced through ports in the upper part of the combustor to complete the combustion process. If good mixing between air and combustible waste is achieved, the amount of excess air required for complete combustion can be reduced. In addition, by adding limestone to the bed, SO_2 and HCl can be removed from the flue gas to reduce acid gas emissions.

6.2 SELECTION OF MODEL PLANT SIZES AND OPERATING CHARACTERISTICS

Table 6-1 lists existing FBC plants built since 1985 and those in the advanced planning or construction stage for which information on combustion type, size, and number is available. Figure 6-1 shows the combustor size distribution for these facilities. Figure 6-2 shows the facility size distribution for all facilities either recently built or in the advanced planning or construction stage. Two different design types of FBC's are expected to predominate the FBC population, bubbling bed FBC's and circulating fluidized-bed FBC's. Therefore, two model plants were selected; both combust 100 percent RDF. As is shown in Table 6-1, the newer and planned FBC's are larger than the first two FBC's built, the median combustor size is about 450 TPD, and the majority of the plants have two combustors. Therefore, the two model plants selected are:

- 2 bubbling bed combustors at 450 TPD firing 100 percent RDF
- 2 circulating fluidized-bed combustors at 450 TPD firing 100 percent RDF

6.3 PROJECTED NUMBER OF EACH MODEL PLANT SUBJECT TO NSPS IN 5-YEAR PERIOD AFTER PROPOSAL

Approximately 5,400 TPD of the total projected capacity (on an annual waste flow of 1.8 million tons/year) is represented by FBC's.[4] Of the

TABLE 6-1. FBC FACILITY INFORMATION[a]

EPA REGI	CITY	STATE	COMBUSTOR TYPE	TOTAL PLANT CAPACITY (TPD)	# OF COMBUSTORS	UNIT SIZE (TPD)	CO-FIRING	HEAT RECOVERY	CONTROL TYPE	STARTUP DATE	REFERENCES
5	DULUTH	MN	FBC (BB)	400	2	200	SLUDGE/WOOD	YES	C/VWS	1986	CITY CURRENTS 10/87, WASTE AGE 11/87, MPCA SUBMITTAL 3/31/87
5	LA CROSSE COUNTY	WI	FBC (BB)	400	2	200	WOOD	YES	EGB	1987	CITY CURRENTS 10/87, DIRECT CALL TO COUNTY 3/88
10	TACOMA	WA	FBC (BB)	1000	2	500	COAL/WOOD	YES	BH	1989	WASTE AGE 11/87, MCILVAINE 2/88
3	ERIE COUNTY	PA	FBC (CFB)	850	2	425	NO	YES	FI/BH	UNKNOWN	CITY CURRENTS 10/87, MCILVAINE 2/88, DIRECT CALL TO CITY 1/88
10	COEUR D'ALENE	ID	FBC (BB)	350	1	350	WOOD	YES	FI/BH	UNKNOWN	DIRECT CALL TO CITY 5/89
5	ROBBINS	IL	FBC (CFB)	1200	2	600	NO	YES	FI/BH	1989	DIRECT CALL TO CITY 5/89

[a] Contains existing facilities built since 1985 and facilities in the advanced stages of planning.

FBC = fluidized-bed combustor

BB = bubbling bed

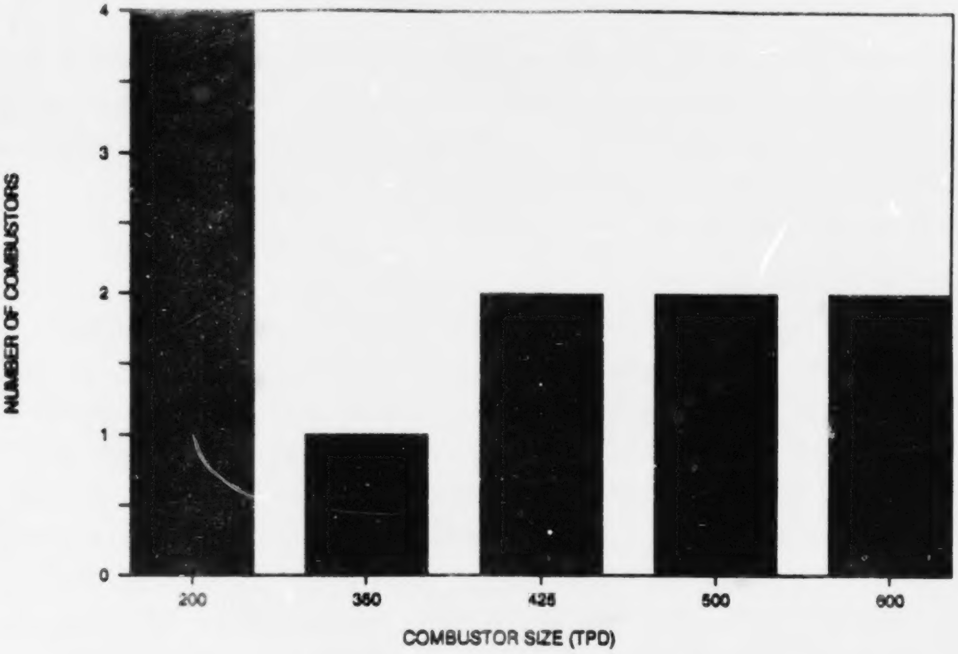

Figure 6-1. FBC combustor unit sizes.

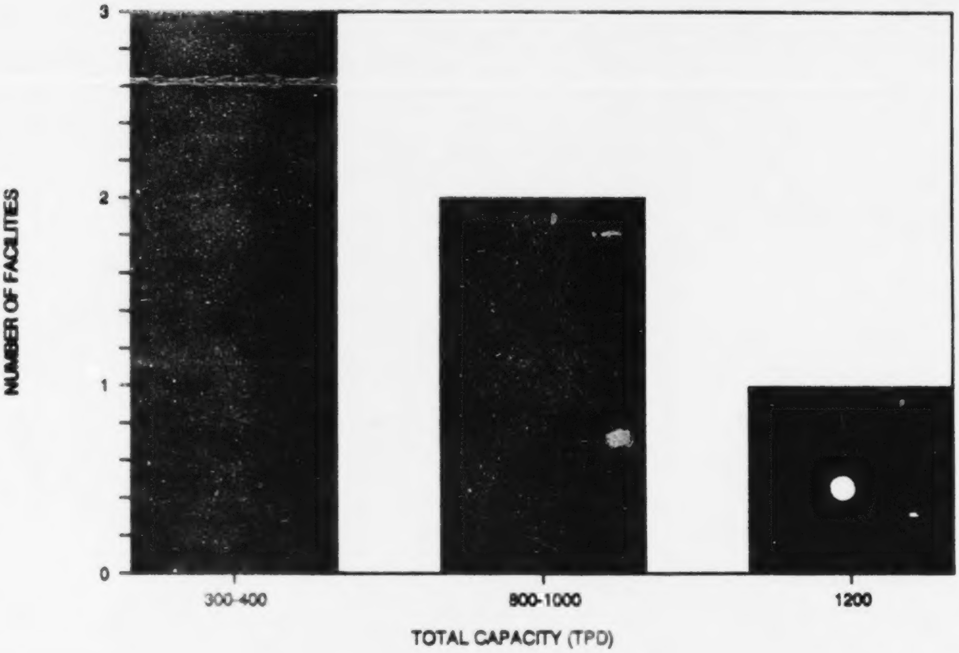

Figure 6-2. FBC facility sizes.

plants planned to start up in 1989 or later, half are bubbling bed and half are circulating fluidized bed. Dividing the total FBC capacities by the model plant size yields a projection of 3 bubbling bed FBC plants with a total of 6 combustors and 3 circulating fluidized-bed plants with a total of 6 combustors that are subject to the NSPS.

6.4 MODEL PLANT PARAMETERS

Table 6-2 lists the parameters for the FBC model plants. The table lists the specifications for each model plant and emission estimates for PM, HCl, SO_2, CO, and total CDD/CDF on both a concentration and mass rate basis. Estimated emission rates of PM, HCl, SO_2, CO, and total CDD/CDF from the bubbling bed FBC model plant are 0.01 gr/dscf, 350 ppmv, 240 ppmv, 50 ppmv, and 20 ng/dscm, respectively. Emission rates of PM, HCl, SO_2, CO, and total CDD/CDF from the circulating fluidized-bed model plant are 0.01 gr/dscf, 350 ppmv, 240 ppmv, 100 ppmv, and 400 ng/dscm, respectively. All flue gas concentrations are reported on a 7 percent O_2, dry basis. The excess air level for the bubbling bed and circulating fluidized-bed units is 60 percent. Both FBC model plants are expected to operate 8,000 hours/yr and generate electricity.

TABLE 6-2. FBC MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model Plants[a] FBC (BB) (No. 11)	 FBC (CFB) (No. 12)
Facility Specification		
No. of combustors per model	2	2
Total daily charge rate, TPD	900	900
Annual operating hours	8,000	8,000
Ash content of feed waste, %[b]	7.5	7.5
Excess combustion air, % of theoretical	60	60
PM emission factor, % of feed waste ash[b]	80	80
Baseline PM emission rate, gr/dscf	0.01	0.01
Stack height, ft	200	200
Stack diameter, ft	6.0	6.0
Flue Gas Data Per Combustor[c]		
Volume flowrate:		
dscfm	56,400	56,400
scfm	65,200	65,200
acfm	99,700	99,700
Outlet temperature °F	350	350
Emission Concentrations per combustor at 7% O_2 (dry)[d]:		
Particulate Matter, gr/dscf	4	4
CO, ppmv	50	100
CDD/CDF, ng/dscm	20	400
Acid gas:		
HCl, ppmv	350	350
SO_2, ppmv	240	240
Annual Emissions per combustor:[d]		
PM, tons/yr	7,220	7,220
CO, tons/yr	22.8	46.2
CDD/CDF ($x10^{-2}$), lbs/yr	3.16	63.3
HCl, tons/yr	503	503
SO_2, tons/yr	417	417

[a] FBC - fluidized-bed combustion.
BB - bubbling bed
CFB - circulating fluidized-bed

[b] From Reference No. 8.

[c] Calculated based on the facility specifications in this table and the feed waste composition data from Table 1-3.

[d] Emissions at combustor exit. Annual emissions from the stack are included in Section 7.0. At baseline, stack emissions of PM are assumed to comply with the 0.05 gr/dscf limit as required by 40 CFR 60, Subpart Db. Baseline controls would not affect emissions of the other pollutants listed, and stack emissions would be the same as listed above.

7.0 MODEL PLANT COSTS, ENERGY, AND ENVIRONMENTAL IMPACTS

This section presents costs, energy, and environmental impacts associated with the application of the emission control options for the 12 model plants. The procedures used to estimate capital and operating costs for both the combustors and the APCD's are summarized in Appendix A and discussed in detail in a separate document concerning MWC cost procedures.[6] Energy impacts are presented for electricity consumed by the APCD's and for auxiliary fuel fired in the combustor. Environmental impacts are presented for CDD/CDF, CO, PM, SO_2, and HCl. Also presented are impacts on total solid waste disposal.

7.1 MASS BURN

Based on design and operating parameters presented in Table 2-3 for the five mass burn model plants, costs were estimated for baseline and three control options. Section 7.1.1 presents the costs, energy, and environmental impacts for the mass burn waterwall model plants. Sections 7.1.2 and 7.1.3 present similar information for the mass burn refractory and mass burn rotary combustor models, respectively.

7.1.1 Mass Burn Waterwall

7.1.1.1 Costs and Energy Impacts. Tables 7-1, 7-2, and 7-3 present the capital costs for the 200, 800, and 2,250 TPD mass burn waterwall model plants, respectively. These tables show combustor capital costs as well as the itemized costs for the APCD's associated with each control option. For baseline, total APCD capital costs range from $1,860,000 for the 200 TPD plant to $6,870,000 for the 2,250 TPD plant. The increase in APCD total capital costs for Control Option 1 compared to the baseline ranges from 9 percent for the 200 TPD plant to 20 percent for the 2,250 TPD plant. The increase in APCD capital cost for Control Option 2 compared to baseline ranges from 59 percent for the 200 TPD plant to 114 percent for the 2,250 TPD plant. The increase in APCD capital cost over baseline for Control Option 3 ranges from 219 percent for the 200 TPD plant to 280 percent for the 800 TPD plant. Total plant capital costs for Control Option 3, the most expensive option, are 16 to 20 percent more than the baseline total plant capital costs for the three model plants.

TABLE 7-1. CAPITAL COSTS FOR 200 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 1)
($1000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	17,860	17,860	17,860	17,860
APCD Capital Cost				
Direct Costs:				
PM control[b]	1,200	1,320	636	-
Acid gas control	0	0	292	3,230[d]
Temperature control	0	0	289	0
- Total APCD control	1,200	1,320	1,220	3,230
- Flue gas ducting and fan	99	99	154	127
Total Direct Costs	1,300	1,420	1,370	3,360
Indirect Costs and Contingencies	444	483	1,020	2,000
Monitoring Equipment[c]	120	120	573	573
Total APCD Capital Cost	1,860	2,020	2,960	5,940
Total Plant Capital Cost	19,720	19,880	20,820	23,800

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[a] Includes costs for combustors, ash handling system, cooling tower, CO monitor per combustor, and balance of plant.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-2. CAPITAL COSTS FOR 800 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 2) ($1000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	50,000	50,000	50,000	50,000
APCD Capital Cost				
Direct Costs:				
PM control[b]	1,850	2,210	1,690	-
Acid gas control	0	0	556	6,620[d]
Temperature control	0	0	406	0
- Total APCD control	1,850	2,210	2,650	6,620
- Flue gas ducting and fan	410	410	688	549
Total Direct Costs	2,260	2,620	3,340	7,170
Indirect Costs and Contingencies	771	894	2,600	4,290
Monitoring Equipment[c]	120	120	573	573
Total APCD Capital Cost	3,150	3,630	6,520	12,020
Total Plant Capital Cost	53,150	53,630	56,520	62,020

[a] Includes costs for combustors, ash handling system, cooling tower, turbine, CO monitor per combustor, and balance of plant.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-3. CAPITAL COSTS FOR 2,250 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 3)
($1000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	110,000	110,000	110,000	110,000
APCD Capital Cost				
Direct Costs:				
PM control[b]	3,860	4,870	3,950	-
Acid gas control	0	0	1,100	13,700[d]
Temperature control	0	0	814	0
- Total APCD control	3,860	4,870	5,860	13,700
- Flue gas ducting and fan	1,130	1,130	1,890	1,500
Total Direct Costs	4,990	6,000	7,750	15,200
Indirect Costs and Contingencies	1,700	2,050	6,060	9,090
Monitoring Equipment[c]	180	180	859	859
Total APCD Capital Cost	6,870	8,220	14,700	25,200
Total Plant Capital Cost	116,900	118,200	124,700	135,200

[a] Includes costs for combustors, ash handling system, cooling tower, turbine, CO monitor per combustor, and balance of plant.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

Tables 7-4, 7-5, and 7-6 present the annualized costs for the 200, 800, and 2,250 TPD mass burn waterwall model plants, respectively. These tables show the total combustor annualized costs as well as the itemized APCD annualized costs associated with each control option. Total APCD annualized costs for baseline range from $425,000 for the 200 TPD plant to $1,860,000 for the 2,250 TPD plant. The increase in APCD annualized costs for Control Option 1 compared to baseline ranges from 8 percent for the 200 TPD plant to 16 percent for the 2,250 TPD plant. The APCD annualized cost increase for Control Option 2 over baseline ranges from 161 percent for the 200 TPD plant to 220 percent for the 2,250 TPD plant. For Control Option 3, the APCD cost increase over baseline ranges from 280 percent for the 200 TPD plant to 330 percent for the 800 TPD plant. Total plant annualized costs for Control Option 3, the most expensive option, are 18 to 23 percent more than the total plant annualized costs for the three model plants at baseline.

Tables 7-4, 7-5, and 7-6 also present estimates of electrical and auxiliary fuel requirements for the APCD's and combustors at each model plant. The APCD electrical requirements for baseline range from 110 MWh/yr for the 200 TPD plant to 2,210 MWh/yr for the 2,250 TPD plant. These electrical requirements are based on 5,000 hours of operation for the 200 TPD plant and 8,000 hours of operation for both the 800 and 2,250 TPD plants. The APCD's associated with Control Option 1 consume between 36 and 52 percent more electricity than that for baseline. Similarly, APCD's associated with Control Option 2 consume between 340 and 610 percent more electricity and the APCD's for Control Option 3 consume between 460 and 640 percent more electricity than baseline. Auxiliary fuel use for each control option is the same as that for baseline. Auxiliary fuel consumption on a heat basis ranges from 3.24 billion Btu/yr for the 200 TPD plant to 36.5 billion Btu/yr for the 2,250 TPD plant.

7.1.1.2 Environmental Impacts. Tables 7-7, 7-8, and 7-9 present estimates of environmental impacts for each control option for the 200, 800, and 2,250 TPD mass burn waterwall model plants, respectively. Shown are emission reductions for CDD/CDF, CO, PM, SO_2, and HCl, and the increase in solid waste disposal associated with each control option.

TABLE 7-4. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 200 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 1)

($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	2,190	2,190	2,190	2,190
- Ash Disposal	313	313	313	313
- Capital Recovery	2,350	2,350	2,350	2,350
- Total Combustor Annualized Costs	4,850	4,850	4,850	4,850
APCD Annualized Cost				
Direct Costs:				
- Operating labor	15	15	68	60
- Supervision	2	2	15	9
- Maintenance labor	8	8	33	33
- Maintenance materials	17	19	70[b]	80[b]
- Electricity	5	8	36	38
- Compressed air	0	0	4	5
- Lime	0	0	45	37
- Water	0	0	1	1
- Waste disposal	20	20	39	44
- Monitoring equipment[a]	16	16	215	215
Total Direct Costs	84	89	526	522
Indirect Costs:				
- Overhead	26	27	103	102
- Taxes, insurance, and administration	70	76	96	215
- Capital recovery	245	266	390	781
Total Indirect Costs	341	369	589	1,100
Total APCD Annualized Costs	425	457	1,110	1,620
Total Plant Annualized Costs	5,280	5,310	5,950	6,470
Energy Requirements				
- APCD Electrical Use (MWh/yr)	110	167	785	820
- Auxiliary Fuel Use (10^6 Btu/yr)	3,240	3,240	3,240	3,240

[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $13,000 for bag replacement (2-year life).

TABLE 7-5. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 800 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 2)

($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	5,790	5,790	5,790	6,570
- Ash Disposal	2,000	2,000	2,000	2,000
- Capital Recovery	6,570	6,570	6,570	6,570
- Total Combustor Annualized Costs	14,370	14,370	14,370	14,370
APCD Annualized Cost				
Direct Costs:				
- Operating labor	24	24	108	96
- Supervision	4	4	24	14
- Maintenance labor	13	13	52	53
- Maintenance materials	30	35	197[b]	195[b]
- Electricity	37	49	168	208
- Compressed air	0	0	26	29
- Lime	0	0	290	240
- Water	0	0	7	7
- Waste disposal	127	130	246	284
- Monitoring equipment[a]	16	16	215	215
Total Direct Costs	251	271	1,330	1,340
Indirect Costs:				
- Overhead	43	46	198	184
- Taxes, insurance, and administration	121	140	237	458
- Capital recovery	414	478	857	1,580
Total Indirect Costs	578	664	1,290	2,220
Total APCD Annualized Costs	829	935	2,630	3,560
Total Plant Annualized Costs	15,200	15,310	17,000	17,930
Energy Requirements				
- APCD Electrical Use (MWh/yr)	787	1,070	3,640	4,530
- Auxiliary Fuel Use (10^6 Btu/yr)	12,960	12,960	12,960	12,960

[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $52,000 for bag replacement (2-year life).

TABLE 7-6. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 2,250 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 3)
($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	10,910	10,910	10,910	10,910
- Ash Disposal	5,630	5,630	5,630	5,630
- Capital Recovery	14,470	14,470	14,470	14,470
- Total Combustor Annualized Costs	31,000	31,000	31,000	31,000
APCD Annualized Cost				
Direct Costs:				
- Operating labor	36	36	162	144
- Supervision	5	5	46	22
- Maintenance labor	20	20	80	79
- Maintenance materials	67	80	486[b]	451[b]
- Electricity	101	138	443	571
- Compressed air	0	0	72	83
- Lime	0	0	815	675
- Water	0	0	19	19
- Waste disposal	358	365	693	798
- Monitoring equipment[a]	25	25	322	322
Total Direct Costs	612	669	3,140	3,160
Indirect Costs:				
- Overhead	77	85	376	330
- Taxes, insurance, and administration	267	322	553	974
- Capital recovery	903	1,080	1,930	3,310
Total Indirect Costs	1,250	1,490	2,860	4,610
Total APCD Annualized Costs	1,860	2,160	6,000	7,780
Total Plant Annualized Costs	32,860	33,160	37,000	38,780
Energy Requirements				
- APCD Electrical Use (MWh/yr)	2,210	3,000	9,640	12,430
- Auxiliary Fuel Use (10^6 Btu/yr)	36,450	36,450	36,450	36,450

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[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $146,000 for bag replacement (2-year life).

TABLE 7-7. ENVIRONMENTAL IMPACTS FOR 200 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 1)

Pollutant[a,b]		Control Options		
	Baseline	1	2	3
CDD/CDF Emissions:				
ng/Nm^3	200	200	50	5
Mg/yr	3.2E-5	3.2E-5	8.1E-6	8.1E-7
% Reduction[c]	-	0	75	98
CO Emissions:				
ppmv	50	50	50	50
Mg/yr	9	9	9	9
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.08	0.01	0.01	0.01
Mg/yr	30	4	4	4
% Reduction[c]	-	88	88	88
SO_2 Emissions:				
ppmv	200	200	120	20
Mg/yr	91	91	54	9
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	124	124	25	4
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	64	64	67	67
Mg/yr	12,100	12,100	12,700	12,700
% Increase[c]	-	0.2	6	5

[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

TABLE 7-8. ENVIRONMENTAL IMPACTS FOR 800 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 2)

Pollutant[a,b]	Control Options			
	Baseline	1	2	3
CDD/CDF Emissions:				
ng/Nm^3	200	200	50	5
Mg/yr	2.1E-4	2.1E-4	5.2E-5	5.2E-6
% Reduction[c]	-	0	75	98
CO Emissions:				
ppmv	50	50	50	50
Mg/yr	60	60	60	60
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.05	0.01	0.01	0.01
Mg/yr	118	24	24	24
% Reduction[c]	-	80	80	80
SO_2 Emissions:				
ppmv	200	200	120	20
Mg/yr	581	581	348	58
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	796	796	159	24
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	255	256	270	268
Mg/yr	77,200	77,300	81,500	81,000
% Increase[c]	-	0.1	6	5

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[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

TABLE 7-9. ENVIRONMENTAL IMPACTS FOR 2,250 TPD MASS BURN/WATERWALL MODEL PLANT (NO. 3)

Pollutant[a,b]	Baseline	Control Options 1	Control Options 2	Control Options 3
CDD/CDF Emissions:				
ng/Nm^3	200	200	50	5
Mg/yr	5.8E-4	5.8E-4	1.5E-4	1.5E-5
% Reduction[c]	-	0	75	98
CO Emissions:				
ppmv	50	50	50	50
Mg/yr	169	169	169	169
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.05	0.01	0.01	0.01
Mg/yr	333	67	67	67
% Reduction[c]	-	80	80	80
SO_2 Emissions:				
ppmv	200	200	120	20
Mg/yr	1,630	1,630	980	163
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	2,240	2,240	448	67
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	718	719	758	753
Mg/yr	217,100	217,400	229,300	227,800
% Increase[c]	-	0.1	6	5

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[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

Total CDD/CDF emissions are the same as baseline for Control Option 1. For Control Options 2 and 3, CDD/CDF emissions are reduced by 75 and 98 percent, respectively. No CO emission reductions beyond baseline are expected for the three control options, because good combustion is assumed to be practiced at baseline. Particulate matter emissions are reduced by 88 percent over baseline for each control option for the 200 TPD plant and 80 percent for each control option for the 800 and 2,250 TPD plants. Sulfur dioxide emissions are the same as baseline for Control Option 1 and are reduced by 40 and 90 percent under Control Options 2 and 3, respectively. Similarly, HCl emissions are the same as baseline for Control Option 1 and are reduced by 80 and 97 percent under Control Options 2 and 3, respectively. Finally, the increase in total solid waste disposal over baseline for each model plant is less than 0.5 percent for Control Option 1, 6 percent for Control Option 2, and 5 percent for Control Option 3.

7.1.2 Mass Burn Refractory

7.1.2.1 Costs and Energy Impacts. Table 7-10 presents combustor and APCD capital costs for the 500 TPD mass burn refractory model plant for each control option. Total APCD capital cost for baseline is $2,880,000. The increases in APCD total capital costs for Control Options 1, 2, and 3 over baseline are 20, 100, and 310 percent, respectively. Total plant capital cost for Control Option 3, the most expensive option, is 20 percent more than the total plant capital costs at baseline.

Table 7-11 presents the annualized costs for the 500 TPD mass burn refractory model plant. This table shows total combustor annualized costs as well as itemized APCD annualized costs associated with each control option. Total APCD annualized cost for baseline is $726,000. The increases over baseline in the total APCD annualized costs for Control Options 1, 2, and 3 are 20, 210, and 350 percent, respectively. Total annualized cost for Control Option 3, the most expensive option, is 20 percent more than the total plant annualized costs at baseline.

Table 7-11 also presents estimates of electrical and auxiliary fuel requirements for the APCD's and combustor, respectively, for each control

TABLE 7-10. CAPITAL COSTS FOR 500 TPD MASS BURN/ REFRACTORY MODEL PLANT (NO. 4) ($1000's in December 1987)

		Control Options		
	Baseline	1	2	3
Total Combustor Capital Cost[a]	37,550	37,550	37,550	37,550
APCD Capital Cost				
Direct Costs:				
PM control[b]	1,740	2,200	1,680	-
Acid gas control	0	0	350	6,590[d]
Temperature control	0	0	405	0
- Total APCD control	1,740	2,200	2,440	6,590
- Flue gas ducting and fan	323	323	425	378
APCD Direct Costs	2,060	2,520	2,860	6,970
Indirect Costs and Contingencies	703	860	2,220	4,150
Monitoring Equipment[c]	120	120	573	573
Total APCD Capital Cost	2,880	3,500	5,660	11,700
Total Plant Capital Cost	40,430	41,050	43,210	49,250

[a] Includes costs for combustors, ash handling system, cooling tower, turbine, CO monitor per combustor, and balance of plant.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-11. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 500 TPD MASS BURN/REFRACTORY MODEL PLANT (NO. 4) ($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	5,680	5,680	5,680	5,680
- Ash Disposal	1,250	1,250	1,250	1,250
- Capital Recovery	4,940	4,940	4,940	4,940
- Total Combustor Annualized Costs	11,870	11,870	11,870	11,870
APCD Annualized Cost				
Direct Costs:				
- Operating labor	24	24	108	96
- Supervision	4	4	23	14
- Maintenance labor	13	13	52	53
- Maintenance materials	28	34	177[b]	190[b]
- Electricity	32	48	166	207
- Compressed air	0	0	26	29
- Lime	0	0	181	150
- Water	0	0	7	7
- Waste disposal	78	81	154	177
- Monitoring equipment[a]	16	16	215	215
Total Direct Costs	196	221	1,110	1,140
Indirect Costs:				
- Overhead	41	45	186	182
- Taxes, insurance, and administration	111	135	204	445
- Capital recovery	379	460	744	1,540
Total Indirect Costs	531	640	1,130	2,170
Total APCD Annualized Costs	726	861	2,240	3,300
Total Plant Annualized Costs	12,600	12,730	14,110	15,170
Energy Requirements				
- APCD Electrical Use (MWh/yr)	698	1,060	3,600	4,510
- Auxiliary Fuel Use (10^6 Btu/yr)	8,100	8,100	8,100	8,100

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[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $51,000 for bag replacement (2-year life).

option. The APCD electrical requirement for baseline is 698 MWh/yr. The APCD's associated with Control Options 1, 2, and 3 consume 50, 420, and 550 percent more electricity than baseline, respectively. Auxiliary fuel consumed for baseline and all three control options is 8.1 billion Btu/year.

7.1.2.2 Environmental Impacts. Table 7-12 presents estimates of environmental impacts for each of the three control options applied to a model 500 TPD mass burn refractory plant. Shown are emissions and emission reductions for CDD/CDF, CO, PM, SO_2, and HCl, and increases in solid waste disposal associated with each control option.

Total CDD/CDF emissions are the same as baseline for Control Option 1. For Control Options 2 and 3, CDD/CDF emissions are reduced by 75 and 98 percent, respectively. No CO emission reductions beyond baseline are expected for the three control options because good combustion is assumed to be practiced at baseline. Particulate matter emissions are reduced by 88 percent over baseline for each control option. Sulfur dioxide emissions are the same as baseline for Control Option 1 and are reduced by 40 and 90 percent under Control Options 2 and 3, respectively. Similarly, HCl emissions are the same as baseline for Control Option 1 and are reduced by 80 and 97 percent under Control Options 2 and 3, respectively. Finally, the increase in total solid waste disposal over baseline is less than 0.5 percent for Control Option 1, 6 percent for Control Option 2, and 5 percent for Control Option 3.

7.1.3 Mass Burn Rotary Combustor

7.1.3.1 Costs and Energy Impacts. Table 7-13 presents combustor and APCD capital costs for the 1,050 TPD mass burn rotary combustor model plant. Total APCD capital cost for baseline is $4,130,000. The increases in the APCD total capital costs for Control Options 1, 2, and 3 over baseline are 13, 90, and 280 percent, respectively. Total plant capital cost for Control Option 3, the most expensive control option, is 16 percent more than the total plant capital cost at baseline.

Table 7-14 presents the annualized costs for the 1,080 TPD mass burn refractory model plant. Shown are total combustor annualized costs as well as itemized APCD annualized costs associated with each control option.

TABLE 7-12. ENVIRONMENTAL IMPACTS FOR 500 TPD MASS BURN/REFRACTORY MODEL PLANT (NO. 4)

Pollutant[a,b]	Baseline	Control Options 1	Control Options 2	Control Options 3
CDD/CDF Emissions:				
ng/Nm^3	300	300	75	5
Mg/yr	1.9E-4	1.9E-4	4.9E-5	3.2E-6
% Reduction[c]	-	0	75	98
CO Emissions:				
ppmv	100	100	100	100
Mg/yr	75	75	75	75
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.08	0.01	0.01	0.01
Mg/yr	119	15	15	15
% Reduction[c]	-	88	88	88
SO_2 Emissions:				
ppmv	200	200	120	20
Mg/yr	364	364	218	36
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	497	497	99	15
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	154	160	168	167
Mg/yr	48,200	48,300	51,000	50,600
% Increase[c]	-	0.2	6	5

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[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

TABLE 7-13. CAPITAL COSTS FOR 1,050 TPD MASS BURN/ROTARY COMBUSTOR MODEL PLANT (NO. 5) ($1000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	69,140	69,140	69,140	69,140
APCD Capital Cost				
Direct Costs:				
PM control[b]	2,460	2,860	2,060	-
Acid gas control	0	0	555	8,540[d]
Temperature control	0	0	550	0
- Total APCD control	2,460	2,860	3,170	8,540
- Flue gas ducting and fan	488	488	851	668
Total Direct Costs	2,950	3,350	4,020	9,210
Indirect Costs and Contingencies	1,010	1,140	3,070	5,490
Monitoring Equipment[c]	180	180	859	859
Total APCD Capital Cost	4,130	4,670	7,950	15,600
Total Plant Capital Cost	73,270	73,810	77,090	84,740

[a] Includes costs for combustors, ash handling system, cooling tower, turbine, CO monitor per combustor, and balance of plant.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-14. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 1,050 TPD MASS BURN/ROTARY WATERWALL MODEL PLANT (NO. 5) ($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	7,810	7,810	7,810	7,810
- Ash Disposal	2,630	2,630	2,630	2,630
- Capital Recovery	9,090	9,090	9,090	9,090
- Total Combustor Annualized Costs	19,520	19,520	19,520	19,520
APCD Annualized Cost				
Direct Costs:				
- Operating labor	36	36	162	144
- Supervision	5	5	46	22
- Maintenance labor	20	20	80	79
- Maintenance materials	40	45	221[b]	242[b]
- Electricity	40	55	196	237
- Compressed air	0	0	29	33
- Lime	0	0	380	315
- Water	0	0	8	8
- Waste disposal	167	170	323	372
- Monitoring equipment[a]	25	25	322	322
Total Direct Costs	333	356	1,770	1,770
Indirect Costs:				
- Overhead	60	64	276	257
- Taxes, insurance, and administration	158	180	284	588
- Capital recovery	543	615	1,050	2,050
Total Indirect Costs	761	859	1,610	2,900
Total APCD Annualized Costs	1,100	1,210	3,380	4,660
Total Plant Annualized Costs	20,620	20,730	22,900	24,180
Energy Requirements				
- APCD Electrical Use (MWh/yr)	882	1,200	4,260	5,160
- Auxiliary Fuel Use (10^6 Btu/yr)	17,010	17,010	17,010	17,010

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[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $58,000 for bag replacement (2-year life).

Total APCD annualized costs for baseline is $1,100,000. The increases in APCD annualized costs over baseline are 10, 210, and 320 percent for Control Options 1, 2, and 3, respectively. Total plant annualized cost for Control Option 3, the most expensive option, is 17 percent more than the total plant annualized costs at baseline.

Table 7-14 also presents estimates of electrical and auxiliary fuel requirements for the APCD's and combustors, respectively, for each control option. The APCD electrical requirement for baseline is 882 MWh/yr for this plant. The APCD's associated with Control Options 1, 2, and 3 consume about 40, 380, and 480 percent more electricity than baseline, respectively. Auxiliary fuel consumed for baseline and each control option is 17 billion Btu/year.

7.1.3.2 Environmental Impacts. Table 7-15 presents estimates of environmental impacts of each control option for the 1,050 TPD mass burn rotary combustor model plant. Shown are emissions and emission reductions for CDD/CDF, CO, PM, SO_2 and HCl, and increases in solid waste disposal associated with each control options.

Total CDD/CDF emissions are same as baseline for Control Option 1. For Control Options 2 and 3, CDD/CDF emissions are reduced by 75 and 98 percent, respectively. No CO emission reductions beyond baseline are expected for the three control options because good combustion is assumed to be practiced at baseline. Particulate matter emissions are reduced by 80 percent over baseline for each control option. Sulfur dioxide emissions are the same as baseline for Control Option 1 and are reduced by 40 and 90 percent under Control Options 2 and 3, respectively. Similarly, HCl emissions are the same as baseline for Control Option 1 and are reduced by 80 and 97 percent under Control Options 2 and 3, respectively. Finally, the increase in total solid waste disposal over baseline is less than 0.5 percent for Control Option 1, 6 percent for Control Option 2, and 5 percent for Control Option 3.

TABLE 7-15. ENVIRONMENTAL IMPACTS FOR 1,050 TPD MASS BURN/ROTARY WATERWALL MODEL PLANT (NO. 5)

Pollutant[a,b]	Baseline	Control Options 1	Control Options 2	Control Options 3
CDD/CDF Emissions:				
ng/Nm^3	300	300	75	5
Mg/yr	4.1E-4	4.1E-4	1.0E-4	6.8E-6
% Reduction[c]	-	0	75	98
CO Emissions:				
ppmv	100	100	100	100
Mg/yr	157	157	157	157
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.05	0.01	0.01	0.01
Mg/yr	155	31	31	31
% Reduction[c]	-	80	80	80
SO_2 Emissions:				
ppmv	200	200	120	20
Mg/yr	763	763	457	76
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	1,040	1,040	209	31
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	335	335	354	352
Mg/yr	101,300	101,400	107,000	106,300
% Increase[c]	-	0.1	6	5

[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

7.2 REFUSE-DERIVED FUEL

Based on design and operating parameters presented in Table 2-3 for the two RDF model plants, costs were estimated for baseline and the three control options using cost procedures specifically for MWC applications.

7.2.1 Costs and Energy Impacts

Tables 7-16 and 7-17 present the capital costs for the 2,000 TPD RDF and the 2,000 TPD cofired RDF/wood model plants, respectively. Combustor capital costs and itemized costs for the APCD's associated with each control option are presented. For baseline, total APCD capital cost is $7,740,000 for both the 2,000 TPD RDF plant and the 2,000 TPD RDF cofired plant. The increases in APCD total capital costs over baseline for Control Options 1, 2, and 3 are about 16, 100, and 250 percent for each model plant, respectively. Total plant capital costs for Control Option 3, the most expensive option, are about 14 percent more than the total plant capital costs for both model plants at baseline.

Tables 7-18 and 7-19 present the annualized costs for both RDF plants. These tables show total combustor annualized costs as well as itemized APCD annualized costs associated with each control option. Total APCD annualized costs for baseline are $2,500,000 for the 2,000 TPD RDF plant and $2,400,000 for the 2,000 TPD RDF cofired plant. The increase in APCD annualized costs over baseline for Control Option 1 is about 10 percent for both model plants. The increase in APCD annualized cost over baseline for Control Option 2 is 180 percent for the 2,000 TPD RDF plant and 160 percent for the RDF cofired plant. For Control Option 3, the increase in APCD annualized costs over baseline is 260 percent for the 2,000 TPD RDF plant and 240 percent for the 2,000 TPD RDF cofired plant. Total plant annualized costs for Control Option 3, the most expensive option, are 16 and 18 percent more than the total plant annualized baseline costs for the 2,000 TPD RDF and 2,000 TPD cofired RDF plants, respectively.

Tables 7-18 and 7-19 also present estimates of electrical and auxiliary fuel requirements for the APCD's and combustors, respectively, for each control option. The APCD electrical requirement for baseline is 2,340 MWh/yr for the 2,000 TPD RDF plant and 2,140 MWh/yr for the 2,000 TPD

TABLE 7-16. CAPITAL COSTS FOR 2,000 TPD RDF MODEL PLANT (NO. 6)
($1000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	135,000	135,000	135,000	135,000
APCD Capital Cost				
Direct Costs:				
PM control[b]	4,580	5,510	4,040	-
Acid gas control	0	0	1,390	15,100[d]
Temperature control	0	0	903	0
- Total APCD control	4,580	5,510	6,340	15,100
- Flue gas ducting and fan	1,010	1,010	1,640	1,320
Total Direct Costs	5,590	6,520	7,980	16,400
Indirect Costs and Contingencies	1,910	2,220	6,280	9,800
Monitoring Equipment[c]	240	240	1,150	1,150
Total APCD Capital Cost	7,740	8,980	15,400	27,400
Total Plant Capital Cost	142,740	143,980	150,400	162,400

[a] Includes costs for combustors, primary shredders, magnetic separators, cooling tower, turbine, CO monitor per combustor, and balance of plant.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-17. CAPITAL COSTS FOR 2,000 TPD RDF COFIRED MODEL PLANT (NO. 7)
($1000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	143,800	143,800	143,800	143,800
APCD Capital Cost				
Direct Costs:				
PM control[b]	4,580	5,510	4,040	-
Acid gas control	0	0	1,390	15,100[d]
Temperature control	0	0	903	0
- Total APCD control	4,580	5,510	6,340	15,100
- Flue gas ducting and fan	1,010	1,010	1,640	1,320
Total Direct Costs	5,590	6,520	7,980	16,400
Indirect Costs and Contingencies	1,910	2,220	6,280	9,800
Monitoring Equipment[c]	240	240	1,150	1,150
Total APCD Capital Cost	7,740	8,980	15,400	27,400
Total Plant Capital Cost	151,540	152,780	159,200	171,200

[a] Includes costs for combustors, primary shredders, magnetic separators, cooling tower, turbine, CO monitor per combustor, and balance of plant.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-18. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 2,000 TPD RDF MODEL PLANT (NO. 6) ($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	13,800	13,800	13,800	13,800
- Ash Disposal	1,670	1,670	1,670	1,670
- Capital Recovery	17,800	17,800	17,800	17,800
- Total Combustor Annualized Costs	33,200	33,200	33,200	33,200
APCD Annualized Cost				
Direct Costs:				
- Operating labor	48	48	216	192
- Supervision	7	7	76	29
- Maintenance labor	26	26	105	106
- Maintenance materials	75	87	485[b]	463[b]
- Electricity	108	141	421	532
- Compressed air	0	0	66	76
- Lime	0	0	1,030	853
- Water	0	0	18	18
- Waste disposal	793	801	1,210	1,349
- Monitoring equipment[a]	33	33	429	429
Total Direct Costs	1,090	1,150	4,060	4,050
Indirect Costs:				
- Overhead	94	101	450	393
- Taxes, insurance, and administration	300	350	570	1,050
- Capital recovery	1,020	1,180	2,030	3,600
Total Indirect Costs	1,410	1,630	3,050	5,040
Total APCD Annualized Costs	2,500	2,780	7,100	9,090
Total Plant Annualized Costs	35,700	35,980	40,300	42,290
Energy Requirements				
- APCD Electrical Use (MWh/yr)	2,340	3,060	9,170	11,580
- Auxiliary Fuel Use (10^6 Btu/yr)	32,400	32,400	32,400	32,400

[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $134,000 for bag replacement (2-year life).

TABLE 7-19. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 2,000 TPD RDF COFIRED MODEL PLANT (NO. 7)
($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	14,300	14,300	14,300	14,300
- Ash Disposal	1,850	1,850	1,850	1,850
- Capital Recovery	18,910	18,910	18,910	18,910
- Total Combustor Annualized Costs	35,070	35,070	35,070	35,070
APCD Annualized Cost				
Direct Costs:				
- Operating labor	48	48	216	192
- Supervision	7	7	76	29
- Maintenance labor	26	26	105	106
- Maintenance materials	75	87	473[b]	451[b]
- Electricity	98	128	385	484
- Compressed air	0	0	60	69
- Lime	0	0	536	445
- Water	0	0	16	16
- Waste disposal	704	711	924	997
- Monitoring equipment[a]	33	33	429	429
Total Direct Costs	992	1,040	3,220	3,200
Indirect Costs:				
- Overhead	94	100	450	394
- Taxes, insurance, and administration	300	350	570	1,050
- Capital recovery	1,020	1,180	2,030	3,600
Total Indirect Costs	1,410	1,630	3,050	5,040
Total APCD Annualized Costs	2,400	2,670	6,270	8,240
Total Plant Annualized Costs	37,470	37,740	41,340	43,310
Energy Requirements				
- APCD Electrical Use (MWh/yr)	2,140	2,800	8,380	10,510
- Auxiliary Fuel Use (10^6 Btu/yr)	32,400	32,400	32,400	32,400

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[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $122,000 for bag replacement (2-year life).

RDF cofired plant. The APCD's associated with Control Options 1, 2, and 3 for each plant consume about 30, 290, and 390 percent more electricity than those for baseline. Auxiliary fuel use for each control option is the same as that for baseline. Auxiliary fuel consumption on a heat basis is 32.4 billion Btu/yr for both plants.

7.2.2 Environmental Impacts

Tables 7-20 and 7-21 present estimates of environmental impacts for the control options for the 2,000 TPD RDF and the RDF cofired model plants, respectively. Shown are emissions and emission reductions for CDD/CDF, CO, PM, SO_2, and HCl, and the increase in solid waste disposal associated with the three control options.

Total CDD/CDF emissions are same as baseline for Control Option 1. For Control Options 2 and 3, CDD/CDF emissions are reduced by 75 and 99 percent, respectively. No CO emission reductions beyond baseline are expected for the three control options because good combustion is assumed at baseline. Particulate matter emissions are reduced by 80 percent over baseline for each control option. Sulfur dioxide emissions are the same as baseline for Control Option 1 and are reduced by 40 and 90 percent under Control Options 2 and 3, respectively. Similarly, HCl emissions are the same as baseline for Control Option 1 and are are reduced by 80 and 97 percent under Control Options 2 and 3, respectively. Finally, the increase in total solid waste from baseline is less than 0.5 percent for Control Option 1 for both model plants. Total solid waste disposal for Control Options 2 and 3 increase by 17 and 15 percent over baseline for the 2,000 TPD RDF plant, respectively. For the 2,000 TPD RDF cofired plant, total solid waste disposal increases by 9 and 8 percent for Control Options 2 and 3 over baseline, respectively.

7.3 MODULAR

Based on design and operating parameters presented in Table 2-3 for the three modular model plants, costs were estimated for baseline and the three control options using cost procedures specifically for MWC applications.

TABLE 7-20. ENVIRONMENTAL IMPACTS FOR 2,000 TPD RDF MODEL PLANT (NO. 6)

Pollutant[a,b]	Control Options			
	Baseline	1	2	3
CDD/CDF Emissions:				
ng/Nm^3	1000	1000	250	10
Mg/yr	3.2E-3	3.2E-3	8.0E-4	3.2E-5
% Reduction[c]	-	0	75	99
CO Emissions:				
ppmv	100	100	100	100
Mg/yr	369	369	369	369
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.05	0.01	0.01	0.01
Mg/yr	364	73	73	73
% Reduction[c]	-	80	80	80
SO_2 Emissions:				
ppmv	300	300	180	30
Mg/yr	2,420	2,420	1,450	242
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	2,430	2,430	485	73
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	295	296	345	340
Mg/yr	89,300	89,600	104,000	103,000
% Increase[c]	-	0.3	17	15

[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

TABLE 7-21. ENVIRONMENTAL IMPACTS FOR 2,000 TPD RDF COFIRED MODEL PLANT (NO. 7)

Pollutant[a,b]	Control Options			
	Baseline	1	2	3
CDD/CDF Emissions:				
ng/Nm^3	1000	1000	250	10
Mg/yr	2.8E-3	2.8E-3	7.0E-4	2.8E-5
% Reduction[c]	-	0	75	99
CO Emissions:				
ppmv	100	100	100	100
Mg/yr	328	328	328	328
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.05	0.01	0.01	0.01
Mg/yr	323	65	65	65
% Reduction[c]	-	80	80	80
SO_2 Emissions:				
ppmv	150	150	90	15
Mg/yr	1,330	1,330	798	133
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	250	250	50	8
Mg/yr	1,180	1,180	236	35
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	284	285	311	308
Mg/yr	86,000	86,300	94,000	93,200
% Increase[c]	-	0.3	9	8

[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

7.3.1 Modular/Excess Air

7.3.1.1 Costs and Energy Impacts. Table 7-22 presents the capital costs for the 240 TPD modular/excess air model plant. Combustor capital costs and itemized costs for the APCD's associated with each control option are presented. For baseline, total APCD capital cost is $1,310,000. The increases in APCD total capital costs for Control Options 1, 2, and 3 over baseline are 16, 100, and 270 percent, respectively. Total plant capital cost for Control Option 3, the most expensive option, is 25 percent more than the total plant capital cost at baseline.

Table 7-23 presents the annualized costs for the 240 TPD modular/excess air model plant. This table shows total combustor annualized costs as well as itemized APCD annualized costs associated with each control option. Total APCD annualized cost for baseline is $332,000. The increases in APCD annualized costs over baseline for Control Options 1, 2, and 3 are 14, 200, and 320 percent, respectively. Total plant annualized cost for Control Option 3, the most expensive option, is 23 percent more than the total plant annualized cost at baseline.

Table 7-23 also presents estimates of electrical and auxiliary fuel requirements for the APCD's and combustor, respectively, for each control option. The APCD electrical requirement for baseline is 232 MWh/yr. The APCD's associated with Control Options 1, 2, and 3 consume 50, 450, and 560 percent more electricity than baseline, respectively. Auxiliary fuel consumed for baseline and all three control options is 3.9 billion Btu/year.

7.3.1.2 Environmental Impacts. Table 7-24 presents estimates of environmental impacts for each of the three control options applied to a model 240 TPD modular/excess air plant. Shown are emissions and emission reductions for CDD/CDF, CO, PM, SO_2, and HCl, and increases in solid waste disposal associated with each control option.

Total CDD/CDF emissions are the same as baseline for Control Option 1. For Control Options 2 and 3, CDD/CDF emissions are reduced by 75 and 98 percent, respectively. No CO emission reductions beyond baseline are expected for the three control options because good combustion is assumed to be practiced at baseline. Particulate emissions

TABLE 7-22. CAPITAL COSTS FOR 240 TPD MODULAR/EXCESS AIR MODEL PLANT (NO. 8) ($1000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	13,150	13,150	13,150	13,150
APCD Capital Cost				
Direct Costs:				
PM control[b]	748	901	630	-
Acid gas control	0	0	196	2,670[d]
Temperature control	0	0	176	0
- Total APCD control	748	901	1,000	2,670
- Flue gas ducting and fan	185	185	304	204
Total Direct Costs	930	1,090	1,310	2,870
Indirect Costs and Contingencies	319	371	976	1,710
Monitoring Equipment[c]	60	60	286	286
Total APCD Capital Cost	1,310	1,520	2,570	4,870
Total Plant Capital Cost	14,460	14,670	15,720	18,020

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[a] Includes costs for combustors, waste heat boiler, turbine, CO monitor per combustor, and balance of plant.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-23. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 240 TPD MODULAR/EXCESS AIR MODEL PLANT (NO. 8)
($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	2,030	2,030	2,030	2,030
- Ash Disposal	600	600	600	600
- Capital Recovery	1,730	1,730	1,730	1,730
- Total Combustor Annualized Costs	4,360	4,360	4,360	4,360
APCD Annualized Cost				
Direct Costs:				
- Operating labor	12	12	54	48
- Supervision	2	2	8	7
- Maintenance labor	7	7	27	26
- Maintenance materials	13	15	71[b]	74[b]
- Electricity	11	16	59	71
- Compressed air	0	0	9	10
- Lime	0	0	87	72
- Water	0	0	2	2
- Waste disposal	38	39	74	85
- Monitoring equipment[a]	8	8	107	107
Total Direct Costs	89	98	498	503
Indirect Costs:				
- Overhead	20	21	86	83
- Taxes, insurance, and administration	50	58	92	183
- Capital recovery	173	200	337	640
Total Indirect Costs	243	279	515	906
Total APCD Annualized Costs	332	377	1,010	1,410
Total Plant Annualized Costs	4,690	4,740	5,370	5,770
Energy Requirements				
- APCD Electrical Use (MWh/yr)	232	351	1,280	1,530
- Auxiliary Fuel Use (10^6 Btu/yr)	3,890	3,890	3,890	3,890

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[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $17,000 for bag replacement (2-year life).

TABLE 7-24. ENVIRONMENTAL IMPACTS FOR 240 TPD MODULAR/EXCESS AIR MODEL PLANT (NO. 8)

Pollutant[a,b]	Control Options			
	Baseline	1	2	3
CDD/CDF Emissions:				
ng/Nm^3	200	200	50	5
Mg/yr	6.2E-5	6.2E-5	1.6E-5	1.6E-6
% Reduction[c]	-	0	75	98
CO Emissions:				
ppmv	100	100	100	100
Mg/yr	40	40	40	40
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.08	0.01	0.01	0.01
Mg/yr	57	7	7	7
% Reduction[c]	-	88	88	88
SO_2 Emissions:				
ppmv	200	200	120	20
Mg/yr	174	174	105	17
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	239	239	48	7
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	77	77	81	80
Mg/yr	23,100	23,200	24,500	24,300
% Increase[c]	-	0.2	6	5

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[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

emissions are reduced by 88 percent over baseline for each control option. Sulfur dioxide emissions are the same as baseline for Control Option 1 and are reduced by 40 and 90 percent under Control Options 2 and 3, respectively. Similarly, HCl emissions are the same as baseline for Control Option 1 and are reduced by 80 and 97 percent under Control Options 2 and 3, respectively. Finally, the increase in total solid waste disposal over baseline is less than 0.5 percent for Control Option 1, 6 percent for Control Option 2, and 5 percent for Control Option 3.

7.3.2 Modular/Starved Air

7.3.2.1 Costs and Energy Impacts. Tables 7-25 and 7-26 present the capital costs for the 50 and 100 TPD modular/starved air model plants, respectively. Combustor capital costs and itemized capital costs for the APCD's associated with each control option are presented. For the 50 TPD plant, no capital cost for APCD's is incurred at baseline. Total APCD capital costs for Control Options 1, 2, and 3 are $819,000, $1,400,000, and $2,790,000, respectively. Total APCD capital cost for PM control to 0.08 gr/dscf and temperature control to 450^{0}F is $532,000. This is a level less stringent than Option 1 which the other model plants meet at baseline. Total plant capital cost for Control Option 3, the most expensive option, is 220 percent more than the baseline total plant capital cost for the 50 TPD plant at baseline. For the 100 TPD model plant, total APCD capital cost is $372,000 at baseline. The increases in total APCD capital costs for Control Options 1, 2, and 3 over baseline are 150, 340, and 740 percent, respectively. Total plant capital cost for Control Option 3, the most expensive option, is 50 percent more than the total plant capital cost for the 100 TPD plant at baseline.

Tables 7-27 and 7-28 present the annualized costs for the 50 and 100 TPD model plants, respectively. These tables show the total combustor annualized costs as well as the itemized APCD annualized costs associated with each control option. For the 50 TPD plant, no annualized cost for APCD's is incurred at baseline. Total APCD annualized costs for Control Options 1, 2, and 3 are $197,000, $506,000, and $759,000, respectively. Total APCD annualized cost for PM control to 0.08 gr/dscf and temperature control to 450^{0}F is $142,000. Total plant annualized cost for Control Option 3, the most expensive option, is 120 percent more than the total plant

TABLE 7-25. CAPITAL COSTS FOR 50 TPD MODULAR/STARVED AIR MODEL PLANT (NO. 9) ($1000's in December 1987)

		Control Options			
	Baseline		1	2	3
Total Combustor Capital Cost[a]	1,270	(1,270)[d]	1,270	1,270	1,270
APCD Capital Cost					
Direct Costs:					
PM control[b]	0	(232)[d]	482	258	-
Acid gas control	0	(0)	0	158	1,400[e]
Temperature control	0	(149)	149	149	149
- Total APCD control	0	(381)	631	565	1,550
- Flue gas ducting and fan	0	(33)	61	77	65
Total Direct Costs	0	(414)	692	642	1,610
Indirect Costs and Contingencies	0	(57)	67	469	897
Monitoring Equipment[c]	0	(60)	60	286	286
Total APCD Capital Cost	0	(532)	819	1,400	2,790
Total Plant Capital Cost	1,270	(1,800)	2,090	2,670	4,060

[a] Includes the costs of a CO monitor per combustor and combustors.

[b] PM control equipment used for Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs in parenthesis correspond to PM control at 0.08 gr/dscf at 7 percent O_2 using an ESP and temperature control to 450°F using humidification. Other model plants meet this control level at baseline.

[e] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-26. CAPITAL PLANT COSTS FOR 100 TPD MODULAR/STARVED AIR MODEL PLANT (NO. 10) ($1000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	5,510	5,510	5,510	5,510
APCD Capital Cost				
Direct Costs:				
PM control[b]	265	581	340	-
Acid gas control	0	0	169	1,700[d]
Temperature control	0	0	147	0
- Total APCD control	265	581	656	1,700
- Flue gas ducting and fan	24	71	115	83
Total Direct Costs	289	652	771	1,780
Indirect Costs and Contingencies	23	223	574	1,060
Monitoring Equipment[c]	60	60	286	286
Total APCD Capital Cost	372	935	1,630	3,130
Total Plant Capital Cost	5,880	6,450	7,140	8,640

[a] Includes the costs of a CO monitor per combustor, combustors, waste heat boiler, and turbine.

[b] PM control equipment used for baseline and Control Option 1 is an electrostatic precipitator (ESP). PM control equipment used for Control Options 2 and 3 is a fabric filter (FF).

[c] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[d] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-27. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 50 TPD MODULAR/STARVED AIR MODEL PLANT (NO. 9)
($1,000's in December 1987)

		Control Options			
	Baseline		1	2	3
Combustor Annualized Cost					
- Operating and Maintenance	361	(361)[b]	361	361	361
- Ash Disposal	78	(78)	78	78	78
- Capital Recovery	166	(166)	166	166	166
- Total Combustor Annualized Costs	605	(605)	605	605	605
APCD Annualized Cost					
Direct Costs:					
- Operating labor	0	(12)[b]	12	34	34
- Supervision	0	(2)	2	6	6
- Maintenance labor	0	(8)	8	16	21
- Maintenance materials	0	(5)	8	31[c]	36[c]
- Electricity	0	(0)	1	15	15
- Compressed air	0	(0)	0	2	2
- Lime	0	(0)	0	11	9
- Water	0	(2)	2	3	3
- Waste disposal	0	(0)	0	5	6
- Monitoring equipment[a]	0	(8)	8	107	107
Total Direct Costs	0	(37)	41	230	238
Indirect Costs:					
- Overhead	0	(15)	17	48	54
- Taxes, insurance, and administration	0	(19)	30	44	100
- Capital recovery	0	(70)	108	184	367
Total Indirect Costs	0	(104)	155	276	521
Total APCD Annualized Costs	0	(142)	197	506	759
Total Plant Annualized Costs	605	(747)	802	1,110	1,360
Energy Requirements					
- APCD Electrical Use (MWh/yr)	0	(13)	38	334	322
- Auxiliary Fuel Use (10^6 Btu/yr)	810	(810)	810	810	810

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[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs in parenthesis correspond to PM control at 0.08 gr/dscf at 7 percent O_2 using an ESP and temperature control to 450°F using humidification. Other model plants meet this control level at baseline.

[c] Costs include annual cost of $5,000 for bag replacement (2-year life).

TABLE 7-28. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 100 TPD MODULAR/STARVED AIR MODEL PLANT (NO. 10)

($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance	859	859	859	859
- Ash Disposal	250	250	250	250
- Capital Recovery	725	725	725	725
- Total Combustor Annualized Costs	1,830	1,830	1,830	1,830
APCD Annualized Cost				
Direct Costs:				
- Operating labor	12	12	54	48
- Supervision	2	2	8	7
- Maintenance labor	7	7	27	26
- Maintenance materials	3	9	38[b]	43[b]
- Electricity	1	4	31	32
- Compressed air	0	0	4	4
- Lime	0	0	36	30
- Water	0	0	1	1
- Waste disposal	0	1	15	20
- Monitoring equipment[a]	8	8	107	107
Total Direct Costs	33	42	321	319
Indirect Costs:				
- Overhead	14	17	72	70
- Taxes, insurance, and administration	12	35	54	114
- Capital recovery	49	123	214	411
Total Indirect Costs	75	175	340	595
Total APCD Annualized Costs	108	217	661	914
Total Plant Annualized Costs	1,940	2,050	2,490	2,740
Energy Requirements				
- APCD Electrical Use (MWh/yr)	17	75	666	709
- Auxiliary Fuel Use (10^6 Btu/yr)	1,620	1,620	1,620	1,620

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[a] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[b] Costs include annual cost of $7,000 for bag replacement (2-year life).

annualized cost for the 50 TPD plant at baseline. For the 100 TPD model plant, total APCD annualized cost is $108,000 at baseline. The increases in total APCD annualized costs over baseline for Control Options 1, 2, and 3 are 100, 510, and 750 percent, respectively. Total plant annualized cost for Control Option 3, the most expensive option, is 41 percent more than the total plant capital cost for the 100 TPD plant at baseline.

Tables 7-27 and 7-28 also present estimates of electrical and auxiliary fuel requirements for the APCD's and combustors, respectively, for baseline and each control option. The APCD electrical requirements for baseline for the 50 and 100 TPD plants are 0 and 17 MWh/yr, respectively. The APCD's associated with Control Options 2 and 3 consume about the same amount of electricity for both model plants. Auxiliary fuel use for each control option is the same as that for baseline for each model plant. Auxiliary fuel consumed for the 50 and 100 TPD plants is 0.8 and 1.6 billion Btu/yr, respectively.

7.3.2.2 Environmental Impacts. Tables 7-29 and 7-30 present estimates of environmental impacts for each control option for the 50 and 100 TPD modular/starved air model plants, respectively. Shown are emissions and reductions for CDD/CDF, CO, PM, SO_2, and HCl, and the increase in solid waste disposal associated with the control options.

Total CDD/CDF emissions are the same as baseline for Control Option 1. For Control Options 2 and 3, CDD/CDF emissions are reduced by 75 and 98 percent, respectively. No CO emission reductions beyond baseline are expected for the three control options since all are assumed to operate with good combustion practices. Particulate emissions emissions are reduced by 88 percent over baseline for each control option. Sulfur dioxide emissions are the same as baseline for Control Option 1 and are reduced by 40 and 90 percent under Control Options 2 and 3, respectively. Similarly, HCl emissions are the same as baseline for Control Option 1 and are reduced by 80 and 97 percent under Control Options 2 and 3, respectively. Finally, the increase in total solid waste disposal over baseline for each model plant is less than 0.5 percent for Control Option 1, 6 percent for Control Option 2, and 5 percent for Control Option 3.

TABLE 7-29. ENVIRONMENTAL IMPACTS FOR 50 TPD MODULAR/STARVED AIR MODEL PLANT (NO. 9)

	Control Options			
Pollutant[a,b]	Baseline	1	2	3
CDD/CDF Emissions:				
ng/Nm^3	300	300	75	5
Mg/yr	1.2E-5	1.2E-5	3.0E-6	2.0E-7
% Reduction[c]	-	0	75	98
CO Emissions:				
ppmv	50	50	50	50
Mg/yr	3	3	3	3
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.10 (0.08)[d]	0.01	0.01	0.01
Mg/yr	9 (7)	1	1	1
% Reduction[c]	-	88	88	88
SO_2 Emissions:				
ppmv	200	200	120	20
Mg/yr	23	23	14	2
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	31	31	6	1
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	15	15	16	16
Mg/yr	2,840	2,840	3,010	2,990
% Increase[c]	-	0.3	6	5

[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

[d] Numbers in parantheses for the intermediate control option of PM control to 0.08 gr/dscf at 7 percent O_2 using an ESP and temperature control to 450°F using humidification. Emissions for pollutants other than PM are the same as baseline for this option.

TABLE 7-30. ENVIRONMENTAL IMPACTS FOR 100 TPD MODULAR/STARVED AIR MODEL PLANT (NO. 10)

	Control Options			
Pollutant[a,b]	Baseline	1	2	3
CDD/CDF Emissions:				
ng/Nm^3	300	300	75	5
Mg/yr	3.9E-5	3.9E-5	9.7E-6	6.5E-7
% Reduction[c]	-	0	75	98
CO Emissions:				
ppmv	50	50	50	50
Mg/yr	8	8	8	8
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.08	0.01	0.01	0.01
Mg/yr	24	3	3	3
% Reduction[c]	-	88	88	88
SO_2 Emissions:				
ppmv	200	200	120	20
Mg/yr	72	72	44	7
% Reduction[c]	-	0	40	90
HCl Emissions:				
ppmv	500	500	100	15
Mg/yr	100	100	20	3
% Reduction[c]	-	0	80	97
Total Solid Waste:				
Tons/day	30	30	32	32
Mg/yr	9,080	9,100	9,630	9,560
% Increase[c]	-	0.2	6	5

[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

7.4 FLUIDIZED-BED COMBUSTION

Based on design and operation parameters presented in Table 2-3 for the two FBC model plants, costs were estimated for baseline and the three control options using cost procedures specifically for MWC applications.

7.4.1 Bubbling Bed Fluidized-Bed Combustor

7.4.1.1 Costs and Energy Impacts. Table 7-31 presents the capital costs for the 900 TPD bubbling bed FBC model plant. Combustor capital costs and itemized costs for the APCD's associated with each control option are presented. For baseline, total APCD capital cost is $3,780,000. The APCD total capital cost for Control Option 1 is the same as baseline, and increases 12 and 230 percent for Control Options 2 and 3, respectively. Total plant capital cost for Control Option 3, the most expensive option, is 12 percent more than the total plant capital cost at baseline.

Table 7-32 presents the annualized costs for the 900 TPD bubbling bed FBC model plant. This table shows total combustor annualized costs as well as itemized APCD annualized costs associated with each control option. Total APCD annualized cost for baseline is 1,260,000. The total APCD annualized cost for Control Option 1 is the same as baseline, and increases by 85 and 210 percent for Control Options 2 and 3, respectively. Total plant annualized cost for Control Option 3, the most expensive option, is 14 percent more than the total plant annualized cost at baseline.

Table 7-32 also presents estimates of electrical and auxiliary fuel requirements for the APCD's and combustor for each control option. The APCD electrical requirement for baseline is 3,900 MWh/year. The electrical requirement for the APCD's associated with Control Options 1 and 2 are the same as for baseline, and the APCD's for Control Option 3 use 14 percent more electricity than baseline. Auxiliary fuel consumed for baseline and all three control options is 14.6 billion Btu/year.

7.4.1.2 Environmental Impacts. Table 7-33 presents estimates of environmental impacts for each of the three control options applied to the 900 TPD bubbling bed FBC model plant. Shown are emissions and emission reductions for CDD/CDF, CO, PM, SO_2 and HCl, and solid waste disposal amounts associated with each control option.

TABLE 7-31. CAPITAL COSTS FOR 900 TPD FBC (BUBBLING BED) MODEL PLANT (NO. 11)
($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	70,090	70,090	70,090	70,090
APCD Capital Cost				
Direct Costs:				
PM control	1,980	1,980	1,980	0
Acid gas control (spray dryer)	0	0	0	6,940[c]
- Total APCD control	1,980	1,980	1,980	6,940
- Flue gas ducting and fan	470	470	470	439
Total Direct Costs	2,450	2,450	2,450	7,380
Indirect Costs and Contingencies	1,210	1,210	1,210	4,400
Monitoring Equipment[b]	120	120	573	573
Total APCD Capital Cost	3,780	3,780	4,230	12,340
Total Plant Capital Cost	73,870	73,870	74,320	82,430

---

[a] Includes costs for combustors, primary shredders, magnetic separators, cooling tower, turbine, and balance of plant.

[b] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.[2]

[c] Costs include both a spray dryer system and a fabric filter for PM control.

TABLE 7-32. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 900 TPD FBC (BUBBLING BED) MODEL PLANT (NO. 11)
($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance[a]	8,260	8,260	8,260	8,260
- Ash Disposal	568	568	568	568
- Capital Recovery	9,220	9,220	9,220	9,220
- Total Combustor Annualized Costs	18,050	18,050	18,050	18,050
APCD Annualized Cost				
Direct Costs:				
- Operating labor	48	48	48	96
- Supervision	7	7	7	14
- Maintenance labor	26	26	26	53
- Maintenance materials	187[c]	187[c]	187[c]	210[d]
- Electricity	179	179	179	204
- Compressed air	32	32	32	32
- Lime	0	0	0	122
- Limestone	0	0	480	320
- Water	0	0	0	3
- Waste disposal[e]	0	0	337	311
- Monitoring equipment[b]	16	16	215	215
Total Direct Costs	496	496	1,510	1,580
Indirect Costs:				
- Overhead	122	122	122	186
- Taxes, insurance, and administration	146	146	146	471
- Capital recovery	496	496	555	1,620
Total Indirect Costs	764	764	823	2,280
Total APCD Annualized Costs	1,260	1,260	2,330	3,860
Total Plant Annualized Costs	19,300	19,300	20,380	21,910
Energy Requirements				
- APCD Electrical Use (MWh/yr)	3,900	3,900	3,900	4,440
- Auxiliary Fuel Use (10^6 Btu/yr)	14,580	14,580	14,580	14,580

---

[a] Also includes the costs for electricity, water, overhead, and taxes, insurance, and administrative charges.

[b] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[c] Costs include annual cost of $65,000 for bag replacement (2 year life).

[d] Costs include annual cost of $62,000 for bag replacement (2 year life).

[e] For baseline, and Control Option 1 cost of waste disposal attributed to the APCD is included in the combustor ash disposal costs. Incremental waste disposal costs beyond baseline are shown for Options 2 and 3.

TABLE 7-33. ENVIRONMENTAL IMPACTS FOR 900 TPD FBC (BUBBLING BED) MODEL PLANT (NO. 11)

Pollutant[a,b]	Baseline	Control Options 1	2	3
CDD/CDF Emissions:				
ng/Nm^3	20	20	15	5
Mg/yr	2.87E-05	2.87E-05	2.15E-05	7.17E-06
% Reduction[c]	-	0	25	75
CO Emissions:				
ppmv	50	50	50	50
Mg/yr	41.5	41.5	41.5	41.5
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.01	0.01	0.01	0.01
Mg/yr	32.8	32.8	32.8	32.8
% Reduction[c]	-	0	0	0
SO_2 Emissions:				
ppmv	240	240	75	30
Mg/yr	914	914	286	114
% Reduction[c]	-	0	69	88
HCl Emissions:				
ppmv	350	350	100	10
Mg/yr	759	759	217	23
% Reduction[c]	-	0	71	97
Total Solid Waste:				
Tons/day	68	68	109	105
Mg/yr	20,600	20,600	32,850	31,880
% Increase[c]	-	0	59	55

---

[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

Total CDD/CDF emissions are the same as baseline for Control Option 1. For Control Options 2 and 3, CDD/CDF emissions are reduced only 25 and 75 percent, respectively; however the baseline level (20 ng/Nm^3) is so low relative to other model plants that only a 75 percent reduction is needed to meet the 5 ng/Nm^3 level associated with the most stringent option (Option 3) for the other model plants. No CO emission reductions beyond baseline are expected for the three control options because good combustion is assumed to be practiced at baseline. Particulate emissions are the same for the three control options as for baseline since for this plant, PM emissions are controlled to 0.01 gr/dscf at baseline. Sulfur dioxide emissions are the same as baseline for Control Option 1, and are reduced about 70 and 90 percent for Control Options 2 and 3, respectively. The percent SO_2 control for Option 2 is higher than for other model plants (70 versus 40 percent) because the furnance limestone injection technology used for FBC's under Option 2 removes a greater proportion of SO_2 than the duct sorbent injection technology used for the other model plants under Option 2. Hydrogen chloride emissions are the same as baseline for Control Option 1, and are reduced by 70 and 97 percent for Control Options 2 and 3, respectively. Finally, solid waste disposal for Control Option 1 is the same as baseline, and increases by 59 and 55 percent over baseline for Control Options 2 and 3, respectively.

7.4.2 Circulating Fluidized-Bed Combustor

7.4.2.1 Costs and Energy Impacts. Table 7-34 presents the capital costs for the 900 TPD circulating fluidized-bed FBC model plant. Combustor capital costs and itemized costs for the APCD's associated with each control option are presented. For baseline, total APCD capital cost is $3,780,000. The APCD total capital cost for Control Option 1 is the same as baseline, and increases by 12 and 230 percent for Control Options 2 and 3, respectively. Total plant capital cost for Control Option 3, the most expensive option, is 12 percent more than total plant capital cost at baseline.

Table 7-35 presents the annualized costs for the 900 TPD circulating fluidized-bed FBC model plant. This table shows total combustor annualized costs as well as itemized APCD annualized costs associated with each control option. Total APCD annualized cost for baseline is $1,260,000. The total APCD annualized cost for Control Option 1 is the same as baseline, and

TABLE 7-34. CAPITAL COSTS FOR 900 TPD FBC (CIRCULATING FLUIDIZED-BED) MODEL PLANT (NO. 12) ($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Total Combustor Capital Cost[a]	70,090	70,090	70,090	70,090
APCD Capital Cost				
Direct Costs:				
PM control	1,980	1,980	1,980	0
Acid gas control (spray dryer)	0	0	0	6,940[c]
- Total APCD control	1,980	1,980	1,980	6,940
- Flue gas ducting and fan	470	470	470	439
Total Direct Costs	2,450	2,450	2,450	7,380
Indirect Costs and Contingencies	1,210	1,210	1,210	4,400
Monitoring Equipment[b]	120	120	573	573
Total APCD Capital Cost	3,780	3,780	4,230	12,340
Total Plant Capital Cost	73,870	73,870	74,320	82,430

---

[a] Includes costs for combustors, primary shredders, magnetic separators, cooling tower, turbine, and balance of plant.

[b] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[c] Costs include both a spray dryer system and a fabric filter for PM control.

increases by 140 and 210 percent for Control Options 2 and 3, respectively. Total plant annualized cost for Control Option 3, the most expensive option, is 14 percent more than the total plant annualized cost at baseline.

Table 7-35 also presents estimates of electrical and auxiliary fuel requirements for the APCD's and combustor for each control option. The APCD electrical requirement for baseline is 3,900 MWh/year. The APCD electrical requirement for Control Options 1 and 2 are the same as baseline, and increase by 14 percent for Control Option 3. Auxiliary fuel consumed for baseline and all three control options is 14.6 billion Btu/year.

7.4.2.2 Environmental Impacts. Table 7-36 presents estimates of environmental impacts for each of the three control options applied to the 900 TPD circulating fluidized-bed FBC model plant. Shown are emissions and emission reductions for CDD/CDF, CO PM, SO_2, and HCl and solid waste disposal amounts associated with each control option.

Total CDD/CDF emissions are the same as baseline for Control Option 1. For Control Options 2 and 3, CDD/CDF emissions are reduced by 81 and 99 percent, respectively. No CO emission reductions beyond baseline are expected for the three control options because good combustion is assumed to be practiced at baseline. As with the bubbling bed FBC, particulate emissions are the same for the three control options as for baseline. Sulfur dioxide emissions are the same as baseline for Control Option 1, and are reduced 94 and 88 percent for Control Options 2 and 3, respectively, and are at or below 30 ppmv for both options. Hydrogen chloride emissions are the same as baseline for Control Option 1, and are reduced by 86 and 97 percent for Control Options 2 and 3, respectively. The high SO_2 and HCl percent reductions for Option 2 (relative to other model plants) are due to the high stoichiometric ratio of sorbent (limestone) to acid gas needed to achieve a CDD/CDF level of 75 ng/Nm^3 at the circulating fluidized-bed model plant. Finally, solid waste disposal for Control Option 1 is the same as baseline, and increases by 105 and 55 percent for Control Options 2 and 3, respectively.

7.5 SUMMARY OF COSTS AND ENERGY IMPACTS

Tables 7-37, 7-38, and 7-39 summarize the information on capital costs, annualized costs, and electrical and auxiliary fuel requirements, respectively, for the 12 model plants. Also shown are annual tonnages of waste combusted by each model plant.

TABLE 7-35. ANNUALIZED COSTS AND ENERGY REQUIREMENTS FOR 900 TPD FBC (CIRCULATING FLUIDIZED-BED) MODEL PLANT (NO. 12) ($1,000's in December 1987)

	Control Options			
	Baseline	1	2	3
Combustor Annualized Cost				
- Operating and Maintenance[a]	8,260	8,260	8,260	8,260
- Ash Disposal	568	568	568	568
- Capital Recovery	9,220	9,220	9,220	9,220
- Total Combustor Annualized Costs	18,050	18,050	18,050	18,050
APCD Annualized Cost				
Direct Costs:				
- Operating labor	48	48	48	96
- Supervision	7	7	7	14
- Maintenance labor	26	26	26	53
- Maintenance materials	187[c]	187[c]	187[c]	210[d]
- Electricity	179	179	179	204
- Compressed air	32	32	32	32
- Lime	0	0	0	122
- Limestone	0	0	881	320
- Water	0	0	0	3
- Waste disposal[e]	0	0	595	311
- Monitoring equipment[b]	16	16	215	215
Total Direct Costs	496	496	2,170	1,580
Indirect Costs:				
- Overhead	122	122	122	186
- Taxes, insurance, and administration	146	146	146	471
- Capital recovery	496	496	555	1,620
Total Indirect Costs	764	764	823	2,280
Total APCD Annualized Costs	1,260	1,260	2,990	3,860
Total Plant Annualized Costs	19,300	19,300	21,040	21,910
Energy Requirements				
- APCD Electrical Use (MWh/yr)	3,900	3,900	3,900	4,440
- Auxiliary Fuel Use (10^6 Btu/yr)	14,580	14,580	14,580	14,580

---

[a] Also includes the costs for electricity, water, overhead, and taxes, insurance, and administrative charges.

[b] For PM control, monitoring equipment includes opacity monitor and data reduction system. For PM/acid gas control, monitoring equipment includes opacity, inlet/outlet SO_2, inlet/outlet HCl, and inlet/outlet O_2 monitors and a data reduction system.

[c] Costs include annual cost of $65,000 for bag replacement (2 year life).

[d] Costs include annual cost of $62,000 for bag replacement (2 year life).

[e] For baseline, and Control Option 1 cost of waste disposal attributed to the APCD is included in the combustor ash disposal costs. Incremental waste disposal costs beyond baseline are shown for Options 2 and 3.

TABLE 7-36. ENVIRONMENTAL IMPACTS FOR 900 TPD FBC (CIRCULATING FLUIDIZED-BED) MODEL PLANT (NO. 12)

Pollutant[a,b]	Baseline	Control Options 1	2	3
CDD/CDF Emissions:				
ng/Nm^3	400	400	75	5
Mg/yr	5.74E-4	5.74E-4	1.08E-4	7.17E-6
% Reduction[c]	-	0	81	99
CO Emissions:				
ppmv	100	100	100	100
Mg/yr	83	83	83	83
% Reduction[c]	-	0	0	0
PM Emissions:				
gr/dscf	0.01	0.01	0.01	0.01
Mg/yr	33	33	33	33
% Reduction[c]	-	0	0	0
SO_2 Emissions:				
ppmv	240	240	15	30
Mg/yr	914	914	57	114
% Reduction[c]	-	0	94	88
HCl Emissions:				
ppmv	350	350	50	10
Mg/yr	759	759	108	23
% Reduction[c]	-	0	86	97
Total Solid Waste:				
Tons/day	68	68	140	105
Mg/yr	20,600	20,600	42,210	31,880
% Increase[c]	-	0	105	55

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[a] All flue gas concentrations are reported on a 7 percent O_2, dry basis.

[b] Mass emission rates are for entire model plant.

[c] From baseline.

TABLE 7-37. SUMMARY OF CAPITAL COSTS FOR NEW MWC MODEL PLANTS

Model Plant			Capital Cost ($1000)			
No.	Type[a]	TPY[b]	Baseline	1	2	3
1	MB/WW	41,700	19,720	19,880	20,820	23,800
2	MB/WW	267,000	53,150	53,630	56,520	62,020
3	MB/WW	750,000	116,900	118,200	124,700	135,200
4	MB/REF	167,000	40,430	41,050	43,210	49,250
5	MB/RC	350,000	73,270	73,810	77,090	84,740
6	RDF	667,000	142,740	143,980	150,400	162,400
7	RDF (Cofired)	667,000	151,540	152,780	159,200	171,200
8	MI/EA	80,000	14,460	14,670	15,720	18,020
9	MI/SA	10,400	1,270 (1,800)[c]	2,090	2,670	4,060
10	MI/SA	33,000	5,880	6,450	7,140	8,640
11	FBC (BB)	300,000	73,870	73,870	74,320	82,430
12	FBC (CFB)	300,000	73,870	73,870	74,430	82,430

[a] MB/WW = mass burn/waterwall.
MB/REF = mass burn/refractory.
MB/RC = mass burn/rotary combustor.
RDF = refuse-derived fuel.
MI/EA = modular incinerator/excess air.
MI/SA = modular incinerator/starved air.
FBC = fluidized bed combustion.
BB = bubbling bed
CFB = circulating fluidized-bed

[b] TPY = tons per year.

[c] Cost in parentheses corresponds to PM control at 0.08 gr/dscf at 7 percent O_2 using an ESP and temperature control to 450°F using humidification.

TABLE 7-38. SUMMARY OF ANNUALIZED COSTS FOR NEW MWC MODEL PLANTS

Model Plant			Annualized Cost ($1,000)			
No.	Type[a]	TPY[b]	Baseline	1	2	3
1	MB/WW	41,700	5,280	5,310	5,950	6,470
2	MB/WW	267,000	15,200	15,310	17,000	17,930
3	MB/WW	750,000	32,860	33,160	37,000	38,780
4	MB/REF	167,000	12,600	12,730	14,110	15,170
5	MB/RC	350,000	20,620	20,730	22,900	24,180
6	RDF	667,000	35,700	35,980	40,300	42,290
7	RDF (Cofired)	667,000	37,470	37,740	41,340	43,310
8	MI/EA	80,000	4,690	4,740	5,370	5,770
9	MI/SA	10,400	605 (747)[c]	802	1,110	1,360
10	MI/SA	33,000	1,940	2,050	2,490	2,740
11	FBC (BB)	300,000	19,300	19,300	20,380	21,910
12	FBC (CFB)	300,000	19,300	19,300	21,040	21,910

[a] MB/WW = mass burn/waterwall.
MB/REF = mass burn/refractory.
MB/RC = mass burn/rotary combustor.
RDF = refuse-derived fuel.
MI/EA = modular incinerator/excess air.
MI/SA = modular incinerator/starved air.
FBC = fluidized bed combustion.
BB = bubbling bed
CFB = circulating fluidized-bed

[b] TPY = tons per year.

[c] Cost in parentheses corresponds to PM control at 0.08 gr/dscf at 7 percent O_2 using an ESP and temperature control to 450°F using humidification.

TABLE 7-39. SUMMARY OF ELECTRICAL AND AUXILIARY FUEL REQUIREMENTS FOR NEW MWC MODEL PLANTS

Model Plant			Electrical Requirement (MWh/yr)				Auxiliary Fuel Requirement (10^6 Btu/yr)			
No.	Type[a]	TPY[b]	Baseline	1	2	3	Baseline	1	2	3
1	MB/WW	41,700	110	167	785	820	3,240	3,240	3,240	3,240
2	MB/WW	267,000	787	1,070	3,640	4,560	12,960	12,960	12,960	12,960
3	MB/WW	750,000	2,210	3,000	9,640	12,430	36,450	36,450	36,450	36,450
4	MB/REF	167,000	698	1,060	3,600	4,510	8,100	8,100	8,100	8,100
5	MB/RC	350,000	882	1,200	4,260	5,160	17,010	17,010	17,010	17,010
6	RDF	667,000	2,340	3,060	9,170	11,580	32,400	32,400	32,400	32,400
7	RDF (Co-fired)	667,000	2,140	2,800	8,380	10,510	32,400	32,400	32,400	32,400
8	MI/EA	80,000	232	351	1,280	1,530	3,890	3,890	3,890	3,890
9	MI/SA	10,400	0 (13)[c]	38	334	322	810 (810)[c]	810	810	810
10	MI/SA	33,000	17	75	666	709	1,620	1,620	1,620	1,620
11	FBC (BB)	300,000	3,900	3,900	3,900	4,440	14,580	14,580	14,580	14,580
12	FBC (CFB)	300,000	3,900	3,900	3,900	4,440	14,580	14,580	14,580	14,580

[a] MB/WW = mass burn/waterwall.
MB/REF = mass burn/refractory.
MB/RC = mass burn/rotary combustor.
RDF = refuse-derived fuel.
MI/EA = modular incinerator/excess air.
MI/SA = modular incinerator/starved air.
FBC = fluidized bed combustion.
BB = bubbling bed
CFB = circulating fluidized-bed

[b] TPY = tons per year.

[c] Electrical and auxiliary fuel requirements correspond to PM control at 0.08 gr/dscf using an ESP and temperature control to 450°F using humidification.

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TABLE A-1. CAPITAL AND ANNUALIZED COST PROCEDURES FOR MODULAR MWC's[a,b]

Capital Costs

1. Modular MWC without heat recovery:

   Unit Capital Cost = $24,300 per ton/day of MSW processed

2. Modular MWC producing steam (without generating electricity):

   Unit Capital Cost = $32,500 per ton/day of MSW processed

3. Modular MWC generating electricity:

   Unit Capital Cost = $54,600 per ton/day of MSW processed

4. Total Capital Costs = Unit Capital Costs * TPD

Annualized Costs

1. Operating and Maintenance Costs excluding waste disposal:

   For TPD < 150 and HRS < 6,000,
   Costs = (10 - 0.23 TPD + 0.006 HRS) * Total Capital Costs/100

   Otherwise,
   Costs = (15.7 - 0.00115 TPD) * Total Capital Costs/100

2. Capital Recovery:

   Costs = CRF * Total Capital Costs

3. Waste Disposal of Bottom Ash:

$$\text{Costs} = \frac{1}{24} * \left(\frac{100 - \text{WR}}{100}\right) * \text{TPD} * \text{HRS} * \text{WDC}$$

---

[a] Costs are estimated in December 1987 dollars.

[b] TPD = plant MSW feed rate, tons/day
HRS = hours of operation
CRF = capital recovery factor, 0.1315 based on 10 percent interest rate and 15-year economic life
WR = weight reduction of MSW in the combustor, percent
WDC = waste disposal cost rate, dollars per ton (typically $25/ton)

TABLE A-2. CAPITAL AND ANNUALIZED COSTS PROCEDURES FOR MASS BURN MWC's[a,b]

Capital Costs (dollars per ton/day of MSW processed)

1. Mass burn MWC without electrical generation:

   Unit Capital Costs = $50{,}420\ (430/\text{Size})^{0.39}$

2. Mass burn MWC with electrical generation:

   Unit Capital Costs = $60{,}700\ (430/\text{Size})^{0.39}$

3. Total Capital Costs = Unit Capital Cost * TPD

Annualized Costs

1. Operating and Maintenance Costs excluding waste disposal:

   For mass burn refractory wall MWC,
   Costs = (15.7 - 0.00115 TPD) * Total Capital Costs/100

   For mass burn waterwall MWC,
   Costs = (12.5 - 0.00115 TPD) * Total Capital Costs/100

2. Capital Recovery

   Costs = CRF * Total Capital Costs

3. Waste Disposal of Bottom Ash:

$$\text{Costs} = \frac{1}{24} * \left(\frac{100 - \text{WR}}{100}\right) * \text{TPD} * \text{HRS} * \text{WDC}$$

---

[a] Costs are estimated in December 1987 dollars.

[b] Size = combustor MSW feed rate, tons/day
TPD = plant MSW feed rate, tons/day
HRS = hours of operation
CRF = Capital recovery factor, 0.1315 based on 10 percent interest rate and 15-year economic life
WR = weight reduction MSW in the combustor percent
WDC = waste disposal cost rate, dollars per ton (typically $25/ton)

TABLE A-3. CAPITAL AND ANNUALIZED COST PROCEDURES FOR RDF FACILITIES[a,b]

Capital Costs (dollars per ton/day of RDF processed)

1. Coarse RD facility:

   Unit Capital Costs = 73,600 $(400/\text{Size})^{0.39}$

2. Fluff RDF facility:

   Unit Capital Costs = 161,880 $(315/\text{Size})^{0.39}$

3. Total Capital Costs = Unit Capital Costs * TPD

Annualized Costs

1. Operating and Maintenance Costs excluding waste disposal:

   Costs = (12.5 - 0.00115 TPD) * Total Capital Costs/100

2. Capital Recovery:

   Costs = CRF * Total Capital Costs

3. Waste Disposal of Bottom Ash:

$$\text{Costs} = \frac{1}{24} * \left(\frac{100 - WR}{100}\right) * TPD * HRS * WDC$$

---

[a] Costs are estimated in December 1987 dollars.

[b] Size = combustor RDF feed rate, tons/day
TPD = plant MSW feed rate, tons/day
CRF = capital recovery factor, 0.1315 based on 10 percent interest rate and 15-year economic life
WR = weight reduction of MSW in the combustor, percent
HRS = hours of operation
WDC = waste disposal cost rate, dollars per ton (typically $25/ton)

TABLE A-4. PROCEDURE FOR ESTIMATING CAPITAL COSTS FOR NEW FBC'S (December 1987 dollars)

Total Direct and Indirect Costs:[a]

$$\text{Costs, } 10^3\$ = 64{,}900 * \text{TPD} * (900/\text{TPD})^{0.39}$$

Process Contingency: 20% of total direct and indirect costs

Total Capital FBC Costs: Total direct and indirect costs + process contingency

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[a] TPD = plant municipal waste feed rate, tons/day.

TABLE A-5. PROCEDURE FOR ESTIMATING ANNUAL OPERATING COSTS FOR FBC'S (December 1987 dollars)

Combustor and Balance of Plant (excludes coarse RDF processing area):

Operating labor (based on 10 man-years, 40 hours/week, $12/hr):

$OL = 10 * 40 * 52 * 12 * (TPD/900) = 277.3 * TPD$

Supervision (based on 3 man-years/year, 40 hours/week, 30% wage rate premium over the operating labor wage):

$SPRV = 3 * 40 * 52 * 12 * 1.3 * (TPD/900) = 108.2 * TPD$

Maintenance labor (based on 3 man-years/year, 40 hours/week, 10% wage rate premium over the operating labor wage):

$ML = 3 * 40 * 52 * 12 * 1.1 * (TPD/900) = 91.5 * TPD$

Maintenance materials: 3% of the total capital costs

Electricity (based on 3 MW power consumption, and electricity rate of $0.046/kwh):

$ELEC = 0.153 * TPD * HRS$

Limestone (based on $40/ton for limestone):

$LIMESTONE = 0.02 * LFEED * HRS * N$

Water (based on 3% blowdown rate and $0.05/1,000 gal):

$WC = 1.86 \times 10^{-6} * STM * HRS$

Waste disposal (based on tipping fee of $25/hr):

$AD = 1.25 \times 10^{-2} * N * HRS * WDR$

Overhead: 60% of the sum of all labor costs (operating, supervisory, and maintenance) plus 60% of maintenance materials costs

Continued

TABLE A-5. (CONCLUDED). PROCEDURE FOR ESTIMATING ANNUAL OPERATING COSTS FOR FBC'S (December 1987 dollars)

Coarse RDF Processing Area:

Total Operating and Maintenance Costs (TOT O&M):

$TOT\ O\&M = 4.4 \times 10^{-4} * (12.5 - 0.00115 * TPD) * TDI$

Taxes, Insurance, and Administrative Charges:

4% of the total capital cost

Capital Recovery (based on 15 year life and 10% interest rate):

13.15% of the total capital cost

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[a] OL = operating labor costs, \$/yr
SPRV = supervision costs, \$/yr
ML = maintenance labor costs, \$/yr
ELEC = electricity costs, \$/yr
HRS = hours of operation per year
LIMESTONE = limestone costs, \$/yr
LFEED = limestone feed rate per unit, lb/hr
N = number of combustors
WC = water costs, \$/yr
STM = plant steam production, lb/hr
AD = waste disposal costs, \$/yr
WDR = waste disposal rate per unit (bottom and fly ash collected), lb/hr
TPD = plant municipal waste feed rate, tons/day
TDI = total direct and indirect capital costs for FBC plant, \$

TABLE A-6. PROCEDURES FOR ESTIMATING CAPITAL COSTS FOR ELECTROSTATIC PRECIPITATORS (ESP'S)[a,b]

Design Equation for Massburn and RDF Facilities:

$$SCA = -189.29 \ln \left[\frac{(100 - PMEFF)}{101.89}\right]$$

Design Equation for Modular Units:

- Use above design equation for large modular units whose flue gas flowrate (Q) is greater than or equal to 30,000 acfm
- For small modular units whose Q < 30,000

$$SCA = -285.7 \ln \left[\frac{(100 - PMEFF)}{79.6}\right]$$

Purchased Equipment Costs

ESP for Massburn and RDF plants and large modular plants[c]:
$\text{Costs, } 10^3\ \$ = (305.2 + 0.00738 * TPA) * N$

ESP for small modular plants (Q < 30,000)[c]:
$\text{Costs, } 10^3\ \$ = 1.08 * (96.3 + 0.015 * TPA) * N$

Ductwork:
$\text{Costs, } 10^3\ \$ = 0.7964 * N * Q^{0.5}$

Fan:
$\text{Costs, } 10^3\ \$ = 1.077 * N * Q^{0.96}$

Installation Direct Costs

= 67% of purchased equipment costs for new ESP

(continued)

TABLE A-6. (Continued)

Indirect Costs

= 54% of purchased equipment costs for massburn, RDF, and large modular units with new ESP
= \$14,000 for small modular units with new ESP

Contingency

= 3% of purchased equipment costs

Total Capital Costs

= Purchased equipment costs + installation direct costs + indirect costs + contingency costs

---

[a] Costs are estimated in December 1987 dollars.

[b] PMEFF = particulate matter removal efficiency, percent
SCA = specific collection area, ft^2/1,000 acfm
Q = 125 percent of the actual flue gas flowrate per ESP unit, acfm
TPA = total plate area, ft^2
N = number of ESP units
L = duct length, feet

[c] Includes taxes and freight of eight percent of the ESP equipment costs.

TABLE A-7. PROCEDURE FOR ESTIMATING ANNUAL OPERATING COSTS FOR ESP's[a,b]

Operating Labor (Based on 1 manhour/shift, labor wage of $12/hr): $OL = 1.5 * N * HRS$

Supervision: 15% of the operating labor cost (OL)

Maintenance Labor (Based on 0.5 manhour/shift, 10% wage rate premium over the operating labor wage): $ML = 0.825 * N * HRS$

Maintenance Materials: 1% of the direct capital costs[c]

Electricity for I.D. Fan (Based on 0.5 inch pressure drop W.C. and electricity rate of $0.046/kwh): $FANELEC = 4.50 \times 10^{-6} * FLW * N * HRS$

Electricity Consumed by ESP (Based on 1.5 watts/ft^2 collection area and electricity rate of $0.046/kwh): $ESPELEC = 6.9 \times 10^{-8} * TPA * N * HRS$

Ash Disposal (Based on tipping fee of $25/ton): $AD = 1.25 \times 10^{-2} * N * HRS * WDR$

Overhead: 60% of the sum of all labor costs (operating, supervisory, and maintenance) plus 60% of maintenance materials costs

Taxes, Insurance, and Administrative Charges: 4% of the total capital costs

Capital Recovery (Based on 15 year life and 10% interest rate): 13.15% of the total capital costs

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[a] All costs are estimated in December 1987 dollars.

[b] OL = operating labor costs, $/yr
N = number of ESP units
HRS = hours of operation
ML = maintenance labor costs, $/yr
FANELEC = electricity costs for I.D. fan, $/yr
ESPELEC = electricity costs for ESP, $/yr
FLW = actual flue gas flowrate per unit, acfm
AD = ash disposal costs, $/yr
WDR = waste disposal rate per unit, lb/hr

[c] Direct capital costs are the sum of purchase equipment costs and installation direct costs.

TABLE A-8. PROCEDURES FOR ESTIMATING CAPITAL COSTS FOR DRY SORBENT INJECTION[a,b]

Purchased Equipment Costs, 10^3 $

1. Lime Storage Silo with Vibrator, Baghouse, and Flow Control Value (Based on 15-day lime supply)
   - For storage volumes (V) less than or equal to 2,300 ft^3 (one storage silo per plant),
     $\text{Costs} = 1.05 * (34.2 + 0.016V)$
   - For storage volumes between 2,300 and 4,600 ft^3 (two storage silos per plant),
     $\text{Costs} = 2.10 * (34.2 + 0.016V)$
   - For storage volume greater than 4,600 ft^3 (two storage silos per plant),
     $\text{Costs} = 2.10 * (63 + 0.0038V)$

2. Feed Bins
   - For duct sorbent injection (one feed bin per combustor),
     $\text{Costs} = 0.0906 * N * (SF)^{0.6145}$
   - For furnace sorbent injection (two feed bins per combustor),
     $\text{Costs} = 0.1812 * N * (SF)^{0.6145}$

3. Gravimetric Feeders
   - For duct sorbent injection (one feeder per combustor),
     $\text{Costs} = 1.024 * (0.000289\ SF + 9.293) * N$
   - For furnace sorbent injection (two feeders per combustor),
     $\text{Costs} = 2.048 * (0.000289\ SF + 9.293) * N$

4. Pneumatic Conveyor (Based on 400 Feet Length)

   $\text{Costs} = 1.05 * (26.4 + 0.0073\ SF + 0.4 * [12.8 + 11.23\ SF^{0.23}])\ N$

5. Injection Ports
   - For duct sorbent injection (one injection port per combustor),
     $\text{Costs} = 1.05 * (22.2 + 0.0014\ SF) * N$
   - For furnace sorbent injection (two injection ports per combustor),
     $\text{Costs} = 2.10 * (22.2 + 0.0014\ SF) * N$

(continued)

TABLE A-8. (Continued)

6. Reactor Vessel (optional for duct sorbent injection to increase flue gas and sorbent contact): Costs = $34 * (Q * 1.25/6,150)^{0.64}$

7. Fabric Filter[c]

Costs = $0.1482 * N * Q^{0.7043}$

8. Induced Draft Fan

Costs = $(1.167 * N * Q^{0.96})/1,000$

9. Ductwork

Costs = $(0.8627 * N * L * Q^{0.5})/1,000$

Installation Direct Costs

= 30% of dry sorbent injection equipment costs + 72% of fabric filter and auxiliary equipment costs

Indirect Costs

= 33% of direct costs (equipment + installation costs) for dry sorbent injection + 42% of equipment cost for the fabric filter and auxiliary equipment

Contingency

= 50% of the sum of direct and indirect costs

Total Capital Costs

= Total Direct Costs + Indirect Costs + Contingency Costs

---

[a] All costs are estimated in December 1987 dollars.

[b] SF = lime feed rate per unit, lb/hr
Q = 125 percent of the actual flue gas flowrate to the fabric filter per unit, acfm
V = lime storage silo volume for the plant, ft^3
N = number of units
L = duct length, feet

[c] Fabric filters are used for new applications.

TABLE A-9. PROCEDURES FOR ESTIMATING ANNUAL OPERATING COSTS FOR DRY SORBENT INJECTION[a,b]

Operating Labor (Based on 2 manhours/shift, wage of $12/hr): $OL = 3.0 * N * HRS$

Supervision: 15% of the operating labor cost (OL)

Maintenance Labor: (Based on 0.5 manhour/shift, 10% wage rate premium over the operating labor wage): $ML = 0.825 * N * HRS$

Maintenance Materials: 5% of the direct capital costs of the sorbent injection equipment[c]

Electricity (Based on electricity rate of $0.046/kwh): $ELEC = 5.25 \times 10^{-6} * (251{,}850 + 52.56 * SF) * N * HRS$

Lime: (Based on $80/ton for hydrated lime and acid gas stoichiometric ratio of 2:1): $LIME = 0.04 * SF * N * HRS$

Overhead: [illegible]% of the sum of all labor costs (operating, supervisory, and maintenance) plus 60% of maintenance materials costs

Taxes, Insurance, and Administrative Charges: 4% of the total capital costs

Capital Recovery (Based on 15 year life and 10% interest rate): 13.15% of the total capital costs

---

[a] All costs are estimated in December 1987 dollars.

[b] OL = operating labor costs, $/yr
N = number of units
HRS = hours of operation
ML = maintenance labor costs, $/yr
ELEC = dry sorbent injection electricity costs, $/yr
SF = lime feed rate per unit, lb/hr
LIME = lime costs, $/yr

[c] Direct capital costs are the sum of purchase equipment costs and installation direct costs.

TABLE A-10. PROCEDURES FOR ESTIMATING ANNUAL OPERATING COSTS FOR FABRIC FILTERS[a,b]

Operating Labor (Based on 2 manhours/shift, wage of $12/hr): OL = 3.0 * N * HRS

Supervision: 15% of the operating labor cost (OL)

Maintenance Labor: (Based on 1 manhour/shift, 10% wage rate premium over the operating labor wage): ML = 1.65 * N * HRS

Maintenance Materials: 5% of the direct capital costs of both the fabric filter and auxiliary equipment[c]

Bag Replacement: (Based on $1.35/ft^2, gross air-to-cloth ratio of 3:1, 2 year bag life, and 10% interest rate): BAG = 0.2593 * Q * N

Electricity (Based on 12.5 inches W.C. pressure drop and electricity rate of $0.046/kwh): ELEC = 1.12 x 10^{-4} * FLW * N * HRS

Compressed Air (Based on 2 scfm of air/1,000 acfm flue gas and $0.17/1,000 scfm for compressed air): AIR = 2.01 x 10^{-5} * FLW * N * HRS

Ash Disposal (Based on tipping fee of $25/ton): AD = 1.25 x 10^{-2} * N * HRS * WDR

Overhead: 60% of the sum of all labor costs (operating, supervisory, and maintenance) plus 60% of maintenance materials costs

Taxes, Insurance, and Administrative Charges: 4% of the total capital costs

Capital Recovery (Based on 15 year life and 10% interest rate): 13.15% of the total capital costs

---

[a] All costs are estimated in December 1987 dollars.

[b] OL = operating labor costs, $/yr
N = number of units
HRS = hours of operation
ML = maintenance labor costs, $/yr
BAG = bag replacement costs, $/yr
Q = 125 percent of the inlet flue gas flowrate per unit, acfm
FLW = actual flue gas flowrate per unit, acfm
ELEC = electricity costs, $/yr
AIR = compressed air costs, $/yr
WDR = ash disposal rate from fabric filter per unit, lb/hr

[c] Direct capital costs are the sum of the purchase equipment costs and installation direct costs.

TABLE A-11. PROCEDURES FOR ESTIMATING CAPITAL COSTS OF STAND-ALONE SPRAY DRYER AND SPRAY DRYER/FABRIC FILTERS[a,b]

Direct Costs

SD/FF Unit[c]: Costs, 10^3 \$ = $8.053 * N * (Q)^{0.517}$

Stand-Alone SD Unit: Costs, 10^3 \$ = $8.428 * N * (Q)^{0.460}$

Ductwork[c]: Costs, 10^3 \$ = $(1.3868 * N * L * Q^{0.5})/1{,}000$

Fan[c]: Costs, 10^3 \$ = $(1.8754 * N * Q^{0.96})/1{,}000$

Indirect Costs = 33% of direct costs

Contingency = 20% of sum of direct and indirect costs

Total Capital Investment = Direct Costs + Indirect Costs + Contingency Costs

---

[a] All costs are estimated in December 1987 dollars.

[b] Q = 125% of the actual flue gas flowrate, acfm
N = number of units
L = Duct length per unit, feet

[c] The total installed costs are assumed to be 133 percent of the direct capital costs.

TABLE A-12. PROCEDURE FOR ESTIMATING ANNUAL OPERATING COSTS FOR STAND-ALONE SPRAY DRYERS AND SPRAY DRYER/FABRIC FILTERS[a,b]

Operating Labor for SD/FF (Based on 4 manhours/shift, labor wage of \$12/hr): OL = 6.0 * N * HRS

Operating Labor for SD (Based on 2 manhours/shift, labor wage of \$12/hr): OL = 3.0 * N * HRS

Supervision: 15% of the operating labor cost (OL)

Maintenance Labor for SD/FF: (Based on 2 manhours/shift, 10% wage rate premium over the operating labor wage): ML = 3.3 * N * HRS

Maintenance Labor for SD: (Based on 1 manhour/shift, 10% wage rate premium over the operating labor wage): ML = 1.7 * N * HRS

Maintenance Materials: 2% of the total direct capital costs

Bag Replacement for SD/FF: (Based on \$1.35/ft^2, gross air-to-cloth ratio of 3:1, 2 year bag life, and 10% interest rate): BAG = 0.2593 * Q * N

Electricity for I.D. Fan for SD/FF (Based on 12.5 inches W.C. pressure drop and electricity rate of \$0.046/kwh): FANELEC = 1.12×10^{-4} * FLW * N * HRS

Electricity for I.D. Fan for SD (Based on 5.5 inches W.C. pressure drop and electricity rate of \$0.046/kwh): FANELEC = 4.93×10^{-5} * FLW * N * HRS

Electricity for Atomizer (Based on 6 kw per 1,000 lb/hr of slurry feed + 15 kw and electricity rate of \$0.046/kwh): ATELEC = 0.046 * (0.006 * (SF + WTR) + 15) * N * HRS

Electricity for Pump (Based on 20 feet of pumping height, 10 psi discharge pressure, 10 ft/sec velocity in piping): PUMPELEC = 1.291×10^{-6} * (SF + WTR) * N * HRS

Compressed Air for SD/FF (Based on 2 scfm of air/1,000 acfm flue gas and \$0.17/1,000 scfm for compressed air): AIR = 2.01×10^{-5} * FLW * N * HRS

Water: (Based on Flue gas cooling to 300°F and \$0.50/1,000 gal): WC = 6.00×10^{-5} * WTR * N * HRS

Lime: (Based on \$70/ton for quick lime and acid gas stoichiometric ratio of 2.5:1): LIME = 0.035 * SF * N * HRS
Where $SF = 56 * (SO_2IN/64 + HCLIN/74) * \frac{CARATIO}{0.9}$

(continued)

TABLE A-12. (Continued)

Ash Disposal for SD/FF (Based on tipping fee of \$25/ton): $AD = 1.25 \times 10^{-2} * N * HRS * WDR$

Overhead: 60% of the sum of all labor costs (operating, supervisory, and maintenance) plus 60% of maintenance materials costs

Taxes, Insurance, and Administrative Charges: 4% of the total capital costs

Capital Recovery (Based on 15 year life and 10% interest rate): 13.15% of the total capital costs

---

[a] All costs are estimated in December 1987 dollars.

[b] OL = operating labor costs, \$/yr
N = number of units
HRS = hours of operation
ML = maintenance labor costs, \$/yr
BAG = bag replacement costs, \$/yr
Q = 125 percent of the actual flue gas flowrate to the fabric filter per unit, acfm
FLW = actual flue gas flowrate to the fabric filter per unit, acfm
SF = lime feed rate per unit, lb/hr
WTR = water rate per unit, lb/hr
FANELEC = electricity costs for the fan, \$/yr
ATELEC = electricity costs for the atomizer, \$/yr
PUMPELEC = electricity costs for the the pumps, \$/yr
AIR = compressed air costs, \$/yr
WC = water costs, \$/yr
LIME = lime costs, \$/yr
AD = ash disposal costs, \$/yr
WDR = waste disposal rate, lb/hr
SO_2IN = inlet spray dryer SO_2 emissions, lb/hr
HClIN = inlet spray dryer HCl emissions, lb/hr
CARATIO = acid gas stoichiometric ratio (2.5)

TABLE A-13. PROCEDURES FOR ESTIMATING CAPITAL COSTS FOR HUMIDIFICATION[a,b]

Purchased Equipment Costs, 10^3 $

1. Humidification Chamber and Pumps:

   Costs = $(0.438 * Q + 80{,}220)\ N/1{,}000$

2. Ductwork:

   Costs = $(1.16 * L * Q^{0.5}) * N/1{,}000$

Installation Direct Costs = 56% of Purchase Equipment Costs

Indirect Costs = 32% of Purchase Equipment Costs

Contingency = 3% of the Purchase Equipment Costs

Total Capital Costs = Purchased Equipment Costs + Installation Direct Costs + Indirect Costs

= 191% of Purchase Equipment Costs

---

[a] All costs are estimated in December 1987 dollars.

[b] Q = 125% of the actual flue gas flowrate, acfm
L = duct length per unit, feet
N = number of units

TABLE A-14. PROCEDURE FOR ESTIMATING ANNUAL OPERATING COSTS FOR HUMIDIFICATION[a,b]

Operating Labor (Based on 0.5 manhours/shift, labor wage of \$12/hr): OL = 0.75 * N * HRS

Supervision: 15% of the operating labor cost (OL)

Maintenance Labor: (Based on 0.5 manhour/shift, 10% wage premium over the operating labor wage): ML = 0.825 * N * HRS

Maintenance Materials: 1% of the total capital costs

Electricity for Pumps[c] (Based on 20 feet of pumping height, 100 psi discharge pressure, 10 ft/sec velocity in piping, and electrical rate of \$0.046/kwh): ELEC = 7.3 X 10^{-6} * N * HRS * WTR

Water (Based on \$0.50/1,000 gal)[c]: WC = 6.0 x 10^{-5} * WTR * N * HRS

Overhead: 60% of the sum of all labor costs (operating, supervisory, and maintenance) plus 60% of maintenance materials costs

Taxes, Insurance, and Administrative Charges: 4% of the total capital costs

Capital Recovery (Based on 15 year life and 10% interest rate): 13.15% of the total capital costs

---

[a] All costs are estimated in December 1987 dollars.

[b] OL = operating labor costs, \$/yr
N = number of units
HRS = hours of operation
ML = maintenance labor costs, \$/yr
WTR = water injection rate, lb/hr
ELEC = electricity costs, \$/yr
WC = water costs, \$/yr

[c] WTR = (Tin-Tout) * Qs * (1-MOIST/100)/940

where
Tin = inlet flue gas temperature, ^{o}F
Tout = outlet flue gas temperature, ^{o}F
Qs = flue gas flow rate per unit, scfm
MOIST = moisture content in flue gas, volume percent

TABLE A-15. CONTINUOUS MONITORING COST SUMMARY[a]

Pollutant compliance options	Method	Capital costs ($1,000)	Operating costs ($1,000/yr)[c]	Annualized costs ($1,000/yr)[d]
PM only	Opacity[b]	61	8	16
Acid gas only	SO_2 (inlet and outlet)	67	10	19
	HCl (inlet and outlet)	140	74	92
	O_2/CO_2	19	15	18
	Data Reduction System	31	4	8
	Total	256	103	137
PM + acid gas	Opacity[b]	61	8	16
	SO_2 (inlet and outlet)	67	10	19
	HCl (inlet and outlet)	140	74	92
	O_2/CO_2	19	15	18
	Total	286	107	145

[a] All costs are reported in December 1987 dollars. For multiple control units, multiply these costs by the number of units.

[b] Includes costs for automatic data reduction system.

[c] Based on 2 certifications/year and maintenance requirements of 0.5 manhour/day for both opacity and O_2/CO_2 monitors and 1 manhour/day for SO_2 and HCl monitors.

[d] Annualized costs include annual operating costs and capital charges on equipment and installation costs. Capital charges are based on a 15-year equipment life at 10 percent interest rate.